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International water and food security development: Performance evaluation and assessment of research needs at multiple scales

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INTERNATIONAL WATER AND FOOD SECURITY DEVELOPMENT: PERFORMANCE EVALUATION AND ASSESSMENT OF RESEARCH NEEDS AT MULTIPLE SCALES

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of
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This dissertation is dedicated to my parents and siblings, who have supported me through it all, and to future generations including

Abby, Hannah, Emma and Thomas.

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LIST OF ABBREVIATIONS

AHP- Analytic Hierarchy Process

ANP- Analytic Network Process

CPWF- Challenge Program on Water and Food

CPWF-M- Challenge Program on Water and Food Mekong

MDGs- Millenium Development Goals

JMP- Joint Monitoring Program

R4D- Research for Development

SNA- Social Network Analysis

USAID- United States Agency for International Development

UN- United Nations

UNICEF- United Nations Children's Fund

WASH- Water, Sanitation, and Hygine

WHO- World Health Organization

ABSTRACT

Grady, Caitlin Anne Ph.D., Purdue University, May 2015. International Water and Food Security Development: Performance Evaluation and Assessment of Research Needs at Multiple Scales. Major Professor: Ernest R. Blatchley III.

Water and food security remain the top development challenges of the decade, and perhaps the century. Since the Millennium Development Goals were established in 2000, billions of people have obtained access to more food, better nutrition, improved water, and basic sanitation facilities worldwide. This progress has been accomplished through the dedication of international organizations, non-governmental organizations, country-level governments, private corporations, and individuals at international, regional, and local scales. Truly tremendous strides have been made in water and food provisioning for humans worldwide.

These past two decades have also seen the largest population growth on record, the highest rates of childhood mortality, and climate effects including drought and shifting rainfall that have caused widespread food shortages and death. In 2014, more than one thousand children under the age of 5 died per day of a preventable water related disease, millions of people went without access to adequate nutrition, and billions were without basic sanitation facilities. The current efforts to provide basic human needs including water and food provisioning are not sufficient to end the widespread water related deaths and chronic hunger issues.

The research presented herein focuses on understanding previously implemented water and sanitation programs, as well as current research for development efforts relating to water and food security. Overall, this work begins with an analysis of limitations to previously implemented projects, then moves to an analysis of a subset

of organizations that are implementing water and food development interventions, and finally concludes with a regional example of how future climate change may alter the management and implementation of water and food programs. Specifically, this work addresses: (1) the quality of improved drinking water sources in western Kenya and southern Vietnam; (2) the status of sanitation facilities in western Kenya and southern Vietnam; (3) stakeholder perceptions and research needs of water and food development programs in the Mekong Basin; (4) how project selection tools can leverage social networks; and (5) how climate change knowledge and perceptions could influence management decisions on a regional scale.

These findings suggest that careful attention should be paid to how organizations define and monitor development interventions. Additionally, this work articulates the value of stakeholder acceptability and the opportunity of leveraging social networks to select and prioritize projects that are more likely to succeed in the long term. The evidence derived from the regional study on climate change perceptions, suggests that further research is needed in water and agriculture management strategies for long term resilience. These research needs are identified and described.

CHAPTER 1. INTRODUCTION

1.1 Introduction

Billions of people suffer from inadequate food, unsafe water, or insufficient sanitation facilities every day. Each year, the international community, including government agencies, non-governmental organizations, charitable foundations, private companies, and citizens alike, contribute billions of dollars to fight these Grand Challenges (World Bank, 2014).

While water and food security have been important in communities for centuries, they have emerged as global problems only over the past 30-40 years. Since 2000, the Millennium Development Goals (MDGs) established by the United Nations have sought to address these and other global challenges. In relation to food security, target 1.C of the MDGs, which aimed to halve the proportion of people who suffer from hunger by 2015, is on track to be met (United Nations, 2014). For water and sanitation, the environmental target 7.C established a goal of halving the number of people without access to safe drinking water and basic sanitation by the year 2015 (United Nations, 2014). Recent studies suggest that this goal has been met for drinking water, in that over 2 billion people have gained access to "improved" water and the number of people without access has been reduced to 780 million (UNICEF & WHO, 2014). Unfortunately this goal is not likely to be met for sanitation access since there are still some 2.5 billion people who lack improved sanitation (UNICEF & WHO, 2014).

Despite this tremendous progress, numerous resources have pointed to the ineffective long term sustainability of development interventions. The United Nations and Joint Monitoring Program has identified limitations of these efforts and of their accounting process (UNICEF & WHO, 2013). The Joint Monitoring Program

acknowledges the challenges but does not concretely evaluate the number of projects that may have failed to be sustained for long term use. As early as 1980,1 the United States Agency for International Development (USAID) estimated that nearly half of all development interventions fail and no longer provide access to the citizens they serve within the first five years of implementation (Elmendorf & Isely, 1981). As shown in Table 1.1, the rates of failure or non-functionality of recent water, sanitation, and hygiene (WASH) development interventions as a whole have not improved since the 1981 assessment and failure rates vary widely between project and countries. These ineffective projects do not help anyone. Failed projects hinder the local citizens since, at the very least they lose access to the resource. Additionally, funding is wasted and implementers may lose the trust of the community and their donor.

Table 1.1. Results from Multiple Water and Sanitation Post Implementation Evaluations

Author	Category	Description	Non-function percentage
(Ryan, 2014)	Water	Evaluation of Madagascar WASH sector	27%
(Ryan, 2014)	Sanitation	Evaluation of Madagascar WASH sector	75%
(Shaw & Manda, 2013)	Water	Evaluation of Malawi WASH sector	67%
(Behrens-shah, 2011)	Water	Evaluation of 100 water systems in Kenya	14%
(The World Bank, 2012)	Sanitation	Evaluation of Cambodia WASH	7-85%
(Whittington et al., 2009)	Water	Evaluation of Water program in Bolivia, Peru, and Ghana	5-10%

There are varieties of factors that may influence the long term success or failure of development projects. In the 1980s and 1990s when studies began to show the failure of these projects, a general consensus developed regarding factors for success. Although specifics varied depending on who and where you looked, in general, best practices included involving households in the planning, including women participation, and requiring some monetary buy-in from the owners and operators of the intervention

(Khang & Moe, 2008; Sara & Katz, 1997; Whittington et al., 1998). Trust and communication between project coordinator and task manager have also been shown to be important drivers in successful development projects (Diallo & Thuillier, 2005). Despite these best management practices, even today not all development interventions integrate community driven, women participation, and monetary buy-in. As shown by Whittington et al. (2009), adhering to extensive community inclusion and post-construction support can yield success rates in the 90-95% range after 3-12 years of implementation. On the other hand, the country of Madagascar implemented many water and sanitation programs without a unified national strategy (Ryan, 2014). These programs often followed best practices for improved water interventions but those strategies didn't translate to success in sanitation programs. One reason for this difference was expressed to be the difficult cultural obstacles relating to open defecation as well as continual struggle for health funding from government agencies (Ryan, 2014).

In addition to the importance of community relationships with regards to success and failure of water and sanitation programs, the organizations working within global civil society are also relational (Anheier & Katz, 2004; Castells, 2000). Not only have international development non-governmental organizations been shown to be relational, but they are also cohesive, meaning that for international non-governmental organizations nearly all organizations are reachable within the network which could lead to a coherent actor in the global governance system, one that can address many critical issues synergistically (Katz & Anheier, 2006). The relationships between an organization and the broader network of entities working in the international development community have strong implications for the overall functioning of that organization. The social relationships between development agencies, non-governmental organizations, private companies, and other groups working on development projects play an important role in the overall success of projects and the working community as a whole.

The primary goal of this research was to analyze development practice at multiple scales in order to better understand limitations of current practices and present new suggestions for future improvement. In an attempt to analyze the current status of water and sanitation programs, this work presents findings from water quality tests and

household surveys completed in both southern Vietnam and western Kenya. Then, in order to learn from the organizations working in development practice, stakeholder satisfaction with a large regional development organization was explored. The final two chapters of this dissertation utilize data from both household level assessments and regional stakeholder surveys in order to propose new ways to think about development project selection and regional natural resource management. While the importance of these findings may vary according to specific development cases, this work is needed to improve our ability to help people throughout the world gain access to basic human needs.

1.2 Site Profiles

This research encompasses results from several scales across several countries. The most detailed scale, household level, employed water quality analysis and social survey methodology in Kenya and Vietnam. Both countries have seen progress towards reaching various MDGs however Kenya is not on track to meet MDGs 7.C relating to water and sanitation access. Table 1.2 reports the most recent estimations for improved water and sanitation facilities in each country.

Table 1.2. Percentage of population with improved water and sanitation facilities

	Population access to improved drinking water		Population access to improved sanitation	
	Urban	Rural	Urban	Rural
Vietnam	98%	94%	93%	67%
Kenya	82%	55%	31%	29%

(UNICEF & WHO, 2014)

Ecologically, these two countries vary greatly. Western Kenya, where household surveys were completed, lies within the upper bounds of the Nile River Basin. Additionally, the area of western Kenya studied lies between 7000-9000 feet above mean sea level. Southern Vietnam lies at the outflow of the Mekong River Basin in southeast Asia and nearly all of this area is within 10 feet of sea level. Both areas have highly seasonal rainfall patterns and agriculturally dominated landscapes. Additional details of site selection characteristics are articulated throughout the dissertation chapters.

The regional and global scale analyses focused on organizations working in the Mekong River Basin. The analyses for chapters 4 and 5 were based on data collected in the People's Democratic Republic of Lao, Cambodia, Vietnam, and Thailand and also included input from organizations based in other countries that work in the Mekong Basin. The details of these site profiles are described, where appropriate, throughout the encompassed chapters.

1.3 Specific Aims and Limitations

The specific aims of this work include:

- **Aim 1: To quantify failure rates for water and sanitation interventions in multiple communities**. Village level household surveys and water quality testing were used in southern Vietnam and western Kenya to assess the status previously implemented water and sanitation development interventions.
- **Aim 2**: **To quantify organizational effectiveness through a stakeholder satisfaction evaluation of current development practitioners.** The Challenge Program on Water and Food Mekong was used as the target organization for a stakeholder satisfaction evaluation. A regional stakeholder survey and individual partner interviews were completed to quantify effectiveness through stakeholder satisfaction.
- **Aim 3: To pose new alternatives for development work based on the integration of interdisciplinary data.** Social network data were used to present a new approach to development project selection.

Although the outcomes of this work have general applicability to development agendas in many places, it is important to discuss the limitations of this research. First, this research is meant to provide a glimpse into the current status of water and sanitation projects in a small set of communities. Thus, it is impossible to determine if the lessons learned from these cases will hold true in other communities throughout the world. Additionally, this work only begins to scrape the surface of determining the complex influences on the results presented herein. For example, while policy and political

influences are mentioned within the discussion of these studies, this work is by no means intended to take the place of extensive political and legal studies that may be able to more accurately glean how policies influence water management outcomes. Like policy, more extensive water quality analyses would be able to provide insight into the factors and sources of water contamination identified within. As with many research endeavors outside of a controlled lab, the complexities of political, physical, social, climactic, and other influencers are often hard to identify and quantify. This work provides one of many approaches to target these difficulties in a systematic way.

1.4 Organization

- **Chapter 2:** A post implementation analysis of water quality of improved water sources in western Kenya and southern Vietnam is presented. Utilizing *E. coli* as an indicator organism, the microbial quality of "improved water" sources were examined and compared with a WHO standard for drinking water quality. [Published: Grady, C. A., Kein N., Kipkorir, E. and E.R. Blatchley III. 2014. *Journal of Water and Health*. doi:10.2166/wh.2014.206]
- C**hapter 3:** Building upon the previous chapter on improved access to drinking water, the results of post implementation analyses of sanitation facilities in western Kenya and southern Vietnam are presented. Using data gathered from household surveys, limitations to current development efforts are also presented. [In review]
- **Chapter 4:** The third and final post implementation review of development programs was completed by analyzing stakeholder perceptions and attitudes towards the Challenge Program on Water and Food Mekong. These data illustrate a regional level evaluation which complements the household level evaluations in chapters 2 and 3. [Published: Grady, C. 2014. Evaluation of Project Effectiveness: The Research for Development Model in the Mekong River Basin. Impact Assessment Series.].
- **Chapter 5:** To move towards potential solutions for limitations outlined in chapters 2-4, a new method for prioritizing and selecting potential development projects for funding is presented. Utilizing the Analytic Network Process and

actual social network data, a method is presented for leveraging social network support in order to fund more successful development projects. [Published: Grady, C. A., Xiaozheng He, Srinivas Peeta. 2015. Integrating social network analysis with analytic network process for international development project selection. *Expert Systems with Applications.* 42(12): 5128–5138.].

- **Chapter 6:** The findings of these research studies are summarized and additional avenues for research and international development efforts relating to food, water, and sanitation are discussed.

CHAPTER 2. MICROBIAL QUALITY OF IMPROVED DRINKING WATER SOURCES: EVIDENCE FROM WESTERN KENYA AND SOUTHERN VIETNAM

Reproduced From
Grady, C.A.; Kipkorir. E.; Nguyen, K.; and Blatchley III, E.R. 2014. Microbial quality of improved drinking water sources: Evidence from western Kenya and southern Vietnam. *Journal of Water and Health. In Press*. doi:10.2166/wh.2014.206

2.1 Abstract

In recent decades, more than 2 billion people have gained access to improved drinking water sources thanks to extensive efforts of governments, public, and private sector entities. Despite this progress, many water sector development interventions do not provide access to safe water or fail to be sustained for long term use. The authors examined drinking water quality of previously implemented water improvement projects in three communities in western Kenya and thee communities in southern Vietnam. The cross-sectional study of 219 households included measurements of viable *E. coli*. High rates of *E. coli* prevalence in these improved water sources were found in many of the samples. These findings suggest that measures above and beyond the traditional "improved source" definition may be necessary to insure truly safe water throughout these regions.

2.2 Introduction

Although some 780 million people still do not have access to improved drinking water (UNICEF & WHO, 2013), international water development work has

been widely touted as a major success story of the past 2 decades. Primarily across Africa and Asia, governments, non-governmental organizations, communities, private companies and individuals have brought access to improved drinking water to over 2 billion people, or just under half of the 1990 world population and over one-fourth of today's population. These efforts have been so successful that the United Nations declared the Millennium Development Goal Target 7c accomplished as of 2010, five years ahead of schedule (UNICEF & WHO, 2013). The Joint Monitoring Program of the World Health Organization and United Nations defines improved drinking water simply according to source type which includes: a piped connection into the home, public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, and rainwater collection (United Nations, 2012). Although these source selections are intended to protect drinking water by the nature of their construction, this definition does not directly address finished water quality, and therefore has the potential to misrepresent the number of people with access to safe drinking water (Baum et al., 2014; UNICEF & WHO, 2013).

Due to a number of factors including time, funding, treatment intervention, cultural practices, and laboratory or field technological limitations, it is difficult to define a standard protocol of methodological approaches for evaluating water and sanitation interventions in developing countries. Effectiveness studies traditionally utilize engineering and water quality indicators (eg. Duke et al., 2006; Lee & Schwab, 2005; Sobsey et al., 2008), health epidemiological information (eg. Clasen et al., 2007; Reller et al., 2003), household and community attributes gathered through social science methodology (eg. Peter & Nkambule, 2012; Prokopy et al., 2008; Whittington et al., 2009), or combinations of these three. Most of these effectiveness studies focus on one specific intervention or one implementation protocol and do not evaluate safe water access within a region as a whole. This article, instead of focusing on one implementation strategy, presents a summary of viable *Escherichia coli (E. coli)* concentration measurements for drinking water samples from improved sources in western Kenya and southern Vietnam. One previous study (Baum et al., 2014) has evaluated the relationship between improved water sources and *E. coli* concentrations in the Dominican Republic, concluding that the current estimate of safe water access may be overly optimistic. We

aimed to add to their location-specific finding by measuring viable *E.coli* concentrations evaluations to settings in both east Africa and southeast Asia, thereby further expanding the current knowledge and status of improved water resources worldwide.

We sought to evaluate *E. coli* concentrations for samples collected from water treatment systems in 3 communities in Vietnam and 3 communities in Kenya. In Vietnam, 98% of urban residents and 94% of rural residents have access to improved water sources while in Kenya, the corresponding fractions are 82% and 55%, respectively (UNICEF & WHO, 2014). While both countries are still considered developing, neither country is categorized as a 'least developed county'. Through measurements of viable *E. coli*, these household samples were classified according to the World Health Organization definitions of safe water in order to give a more complete picture of unimproved, improved, and safe water.

2.3 Methods

2.3.1 Site Description

Samples were collected and analyzed between May 2011 and August 2011 in western Kenya and between February 2014 and April 2014 in southern Vietnam. The study designs and protocols were approved by the Purdue University Institutional Review Board (IRB #1105010852 and #1401014379). As shown in **Figure 2.1**, the sample sites in Vietnam included communities near An Phu, Tri Ton, and Bunh Thuy districts. In Kenya, the villages nearby included Kipsinende, Ainabkoi, and Kapsabet. For the sampling procedure in Vietnam, 35 samples from households in each village were collected for microbial analysis totaling 105. In Kenya, 119 households were identified for water sample collection for analysis. These households were distributed throughout each of the three communities and included between 35 and 40 samples per village. Both regions are dominated by agricultural land use, with small areas of urban development and other land cover including rangeland and forests. Sources of water contamination include agricultural runoff as well as human and animal waste. None of the villages have centralized human waste or sanitation facilities, though some specific households have access to improved sanitation such as a ventilated pit latrine. Additionally, all of the

households in Kenya had a point-of-use biosand filtration system and were sampled before and after filtration, thereby totaling 238 water samples.

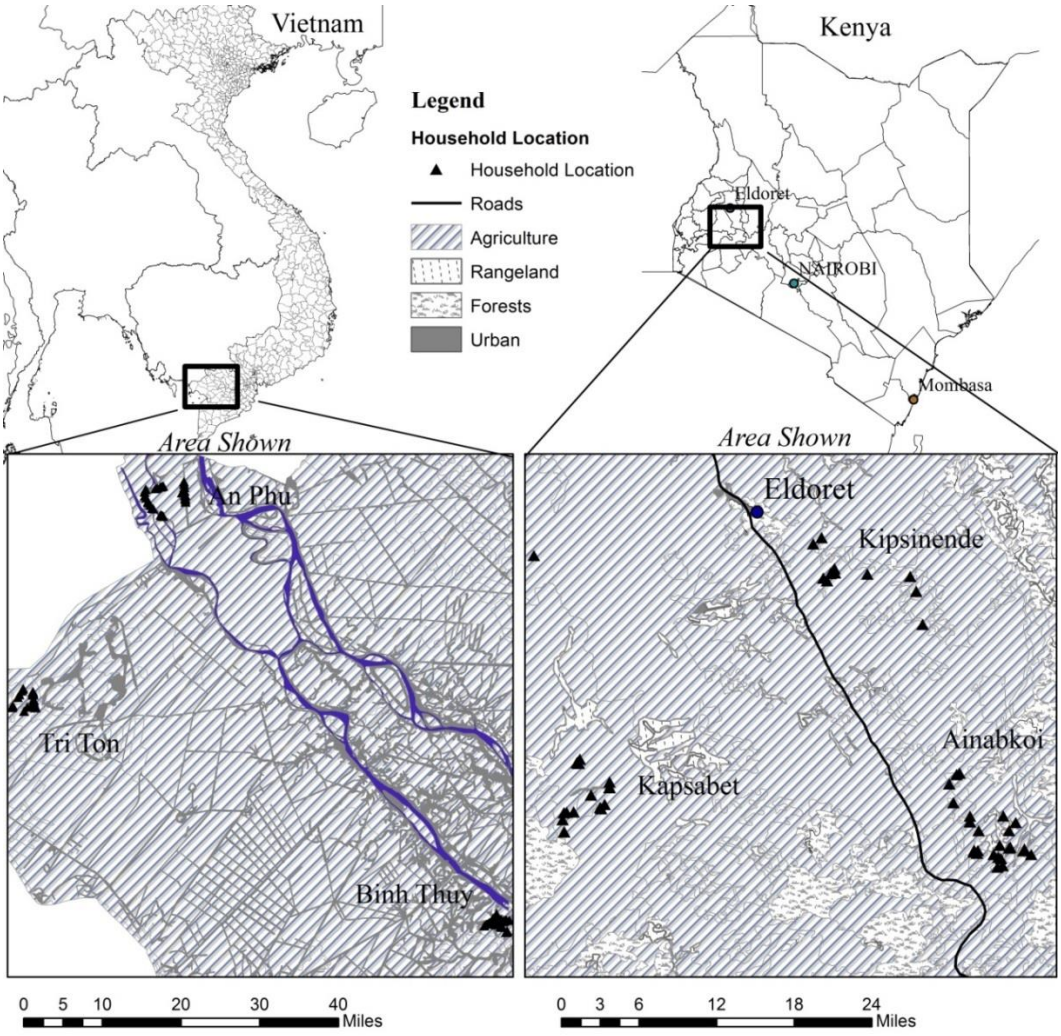

Figure 2.1. Sampling locations for six communities in Kenya and Vietnam.

The household surveys were completed to identify the practices relating to water use and hygiene within the household.

2.3.2 Water Quality Methods

Household water quality was characterized by analyzing the concentration of viable *E. coli* in treated or stored water at the point of use in each household. Water was collected in sterile whirl-pack bags and, due to different field condition constraints, the

samples were analyzed in using different, yet comparable analytical methods for viable *E. coli* in Kenya and Vietnam. In Kenya, the samples collected before and after the point-of-use biosand filters were stored in an ice chest with an approximate temperature of between 3-5° C and brought to Moi University for analysis using a standardized membrane filtration assay, EPA Method 1103.1. In Vietnam, samples were collected and analyzed using the Compartment Bag Test (CBT) developed by Aquagenx (Stauber et al., 2014). This method utilizes a chromogenic *E. coli* broth culture which is mixed with the water sample for 20 minutes prior to pouring into the compartment bag (Stauber et al., 2014). After the sample is poured into a compartment bag, it is sealed with a two-piece plastic bag clip to isolate each compartment for incubation for 18-24 hours at approximately 35°C. After incubation, the presence of *E. coli* in each of five bag compartments of known volume can be determined through a blue-green color due to the hydrolysis of the β–glucuronide substrate (Stauber et al., 2014). A most probable number calculator is then used to estimate the concentration of viable *E. coli* in the original sample. Both sets of samples were processed within approximately 6 hours of the point of collection. Viable *E. coli* were measured because they are a commonly utilized indicator for fecal contamination used by the United Nations, World Health Organization, and a variety of other organizations worldwide (World Health Organization, 2011). Both methods ultimately indicate an estimate of *E. coli* coliform present in the sample and have been shown to produce results consistent with each other (Stauber et al., 2014).

2.4 Results

Of the 105 samples from Vietnam, 102 were from improved water sources, of which piped water was the most prevalent (65%) and rainwater (10%) was the second most common. In Kenya 16 samples were from unimproved sources and 103 samples from improved sources, where rainwater (40%) and protected wells (32%) were the most common sources of improved water. The results were categorized according to the WHO guidelines for drinking-water quality, which articulate *E. coli* risk levels as described in Table 2.1.

Table 2.1. Risk Classifications for *E. coli* Most Probable Number (MPN)/100mL

WHO classification*	***E. coli* MPN/100mL**
Safe/ Low Risk	<1
Questionable Safety/Intermediate Risk	1-10
Unsafe/ High Risk	10-100
Unsafe/Very High Risk	>100

*World Health Organization Risk Classification (WHO, 2011)

As shown in **Figure 2.2** only about 18% of samples from either Kenya or Vietnam showed no measurable *E. coli* colonies detected. In Kenya, roughly 61% of all improved source samples contained high risk or very high risk levels of *E. coli*. In Vietnam, high or very high risk designations were observed in roughly 67% of samples. While there was only one instance of a Vietnamese household with a point-of-use filtration technology (ceramic filter, 0 *E. coli*), all of the piped water on premises was treated with chlorine at a central facility prior to distribution, yet some of these samples still experienced microbial contamination either from household secondary contamination or contamination at some point during the treatment and distribution process.

Point-of-use biosand filters were present at all households sampled in each of the three villages in Kenya. In order to evaluate both the improved sources of water as well as the biosand filters, water samples from both pre-filter, and post-filter (point-of-use) were collected. As summarized in

Table 2.2, the biosand filters did contribute

to an overall reduction of the concentration of viable *E. coli*, but did not yield samples with water quality that consistently met the WHO definition of safe water.

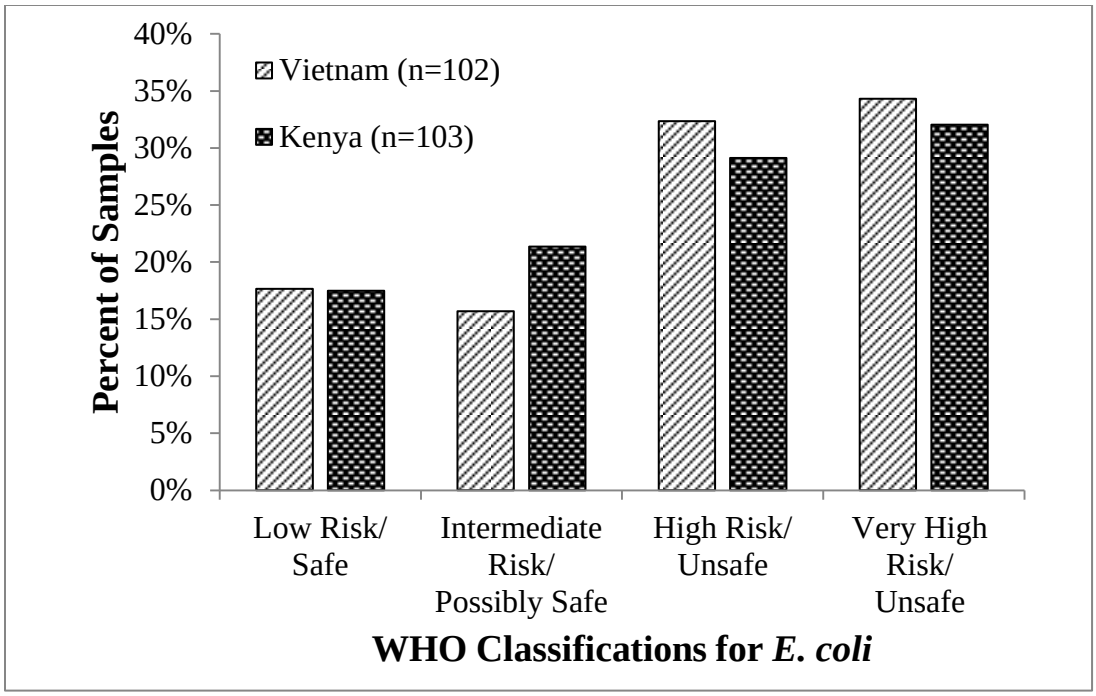

Figure 2.2. Percent of improved source samples with associated *E. coli* risk.

Table 2.2. Variation in percent of *E. coli* presence between pre-and post-filtration of improved and unimproved water sources in Kenya.

	Improved Sources (n=103)		**Unimproved Sources (n=16)**	
***E. coli* Risk Categories**	Pre- Filter	Post Filter	Pre- Filter	Post Filter
Low Risk/Safe	17.6%	24.3%	6.3%	6.3%
Intermediate Risk/Possibly Safe	21.6%	30.1%	0.0%	18.8%
High Risk/Unsafe	28.4%	35.9%	25.0%	50.0%
Very High Risk/Unsafe	32.4%	9.7%	68.8%	25.0%

These results point to an overall trend of decreasing, yet still present viable *E. coli* concentrations in drinking water of households in these three communities in Western Kenya. For example, for both improved and unimproved water sources, the water samples that fell within the very high risk category before the filter, tended to be distributed between lower categories after the biosand filter.

2.5 Discussion and Conclusion

These results show that *E. coli* are prevalent in improved water samples in all six communities in Kenya and Vietnam. These findings indicate that improved drinking water, as defined by the WHO, does not necessarily indicate safe drinking water. These data also contribute to a deeper understanding of the relationship between the categories of "improved" and "unimproved" and measures of fecal indicator bacteria.

Of particular interest is the presence of microbial contamination in the Vietnamese communities because these samples include a large percentage of piped water supplies. Even though this study did not determine the cause of contamination, throughout the data collection, multiple observations of broken and leaking pipes, as well as pipes that were in direct contact with surface water were observed. These distribution problems can lead to contamination within the distribution system (Bhunia et al., 2009; LeChevallier et al., 2003). In Kenya, high rates of microbial contamination both before a secondary point-of-use treatment as well as after were also found. This could be due to the general performance of biosand filters which can range from 0 to 99.7% reduction in typical households (Stauber et al., 2006) or secondary contamination occurring in the household prior to consumption. These results therefore also highlight the importance of safe storage education and household hygiene education, both of which can contribute to a lower level of secondary contamination.

Additionally, as supported by other recent literature (Baum et al., 2014), these results illustrate a need to consider water quality in addition to water source characteristics when classifying water as "improved" or "unimproved". Although monitoring water quality is often limited by resources and capacities in developing and emerging countries, it is difficult to determine water safety without these measures. In recent years, there have also been tremendous gains in field stable rapid *E.* coli test kits (Stauber et al., 2014). These gains now allow microbial water quality testing to move out of the domain of scientist-specific knowledge and into the practitioner field skill set. The tremendous progress that has been made in the water development community over recent decades is truly revolutionary, considering so many of the other Millennium Development Challenges are far from being accomplished. As we look towards the post-

2015 development agenda however, it is important to consider the limited scope of the current “improved” sources definition and how the international community defines and provides water access to people worldwide.

CHAPTER 3. INFLUENCES AND BARRIERS TO IMPROVED WATER AND SANITATION FACILITIES: EVIDENCE FROM THE VIETNAMESE MEKONG DELTA

Reproduced From
Grady, C.A.; Prokopy, L.S., Nguyen, K.; and Blatchley III, E.R. 2015. Influences and barriers to improved water and sanitation facilities: Evidence from the Vietnamese Mekong Delta. *In Review*.

3.1 Abstract

Tremendous strides in providing access to water and sanitation have been made in recent decades. Through the Millennium Development Goal (MDG) 7.C, which sought to halve the proportion of the population without sustainable access to safe drinking water and basic sanitation, billions of people have gained access to these basic human rights. Over 2 billion people have been provided with access to improved drinking water and over 1.3 billion have gained access to basic sanitation facilities since 1990. Despite this progress, there have been discussions over the shortfalls of the United Nations definitions for improved water and sanitation (UNICEF and WHO, 2013). Recent studies on improved drinking water sources have pointed to a need to include quality measures in future development agendas (Baum *et al.*, 2014; Grady *et al.*, 2014). Unfortunately, very few studies focus on the post-implementation phase of sanitation projects in developing and emerging countries. This work addresses this gap by providing insight into the trends and limitations of previously implemented water and sanitation facilities in the Vietnamese Mekong Delta. First, overall access of improved drinking water and basic sanitation facilities in the Vietnamese Mekong Delta were evaluated. Then, social surveys (Appendix B)

were utilized to investigate relationships between household characteristics and access to improved water and sanitation facilities in this region. Finally, a binary logit regression was performed to identify household characteristics that influence access to improved water and sanitation. Through this study, coverage gaps and additional measures are outlined as suggestions for future development protocols.

3.2 Introduction

Water and sanitation development has been a top priority for many local, regional, and international organizations worldwide. Through collaboration among the United Nations, World Health Organization, country governments, non-governmental organizations, and private corporations, billions of people have gained access to water and sanitation in recent decades. Providing access to improved sanitation facilities has remained a more difficult challenge than providing improved drinking water sources due to the complex nature of both engineering and societal challenges (Fry *et al.*, 2008; Grady *et al.*, 2014; Moe and Rheingans, 2006; UNICEF, 2006; UNICEF and WHO, 2014). Moe (2006) identified several limitations including declining international investment, poor marketing of sanitation products, and not learning from mistakes of previously implemented projects. The Water and Sanitation Program of the World Bank articulated several reasons why sanitation interventions have not progressed as rapidly as water interventions, including the lack of capacity of local governments to manage such interventions, ineffective or corrupt incentive programs, a lack of private investments, and difficulties overcoming societal norms (Perez *et al.*, 2012). While sanitation coverage remains an unachieved Millennium Development Goal, access to improved water also needs improvement due to the gaps in rural coverage, inequity for women and marginalized communities, and inadequacy of "improved sources" providing safe water (Baum *et al.*, 2014; Grady *et al.*, 2014; UNICEF and WHO, 2013, 2014). The definitions of both improved water sources and improved sanitation facilities leave large gaps in the overall safety and health benefit that these interventions are intended to provide within communities.

The definitions of improved versus unimproved water and sanitation facilities were put into practice, in part because measures of safety and quality cannot easily be monitored (UNICEF and WHO, 2013). Access to improved water supply simply indicates that citizens receive water from one of the following sources: piped water connection located inside the home or yard, protected dug wells, public taps or standpipes, protected springs, tube wells or boreholes, and rainwater collection (United Nations, 2012). For sanitation facilities the list of technologies include: flush/pour-flush toilets or latrines connected to a sewer, ventilated improved pit latrines, pit latrines with a slab or platform, and composting toilets/latrine (United Nations, 2012). Although the United Nations refers to these distinctions as "improved drinking water" and "basic sanitation facilities", for the purpose of this work, improved water and sanitation refer to the above definition while all other technologies are considered "unimproved" for both water and sanitation. As a part of this definition however, UNICEF and the Joint Monitoring Program (JMP) of the World Health Organization adopted the measure of "use" of these facilities as a necessary component in obtaining a realistic estimate of country wide coverage levels (UNICEF and WHO, 2013). Unfortunately, usage is also difficult to measure as it requires large surveys to be conducted throughout these countries. In addition to usage, the JMP is investigating how water and sanitation access in the lowest income urban housing, slums, compares to other urban areas with factors including the time to source, gender disparities, and household water treatment facilities for consideration in future development strategies (UNICEF and WHO, 2013).

Of the previous studies of water and sanitation interventions, most have focused on drinking water quality, levels of satisfaction, community practices and attitudes, or health indicators as measures of success (Clasen *et al.*, 2007; Esrey and Potash, 1991; Freeman *et al.*, 2012; Prokopy, 2005; Whittington *et al.*, 1993, 2009). While these studies provide important insights into potential limitations of previously implemented programs, they do not convey information about the households without access to improved water and sanitation. Additionally, much of the literature is dominated by studies of water interventions, leaving much to be explored with regard to sanitation access. These two gaps suggest a need for additional research on not only previously implemented water

and sanitation interventions, but also the variation between those with and without access. As a case study, this work was designed to investigate the usage and status of both water and sanitation facilities in the Vietnamese Mekong Delta.

In Vietnam, 93% of the urban population and 67% of the rural population have access to improved sanitation facilities (UNICEF and WHO, 2014). For drinking water, the access rates to improved water are higher, 98% and 94% respectively (UNICEF and WHO, 2014). In the Vietnamese Mekong River Delta there are currently no operational large-scale traditional wastewater treatment plants, although several are currently under construction. Water access in Southeast Asia has rapidly expanded since the implementation of the MDGs. In 1990, 71% of the Southeast Asian population had access to improved water. The improved water coverage grew to 88% of the population by 2010. The basic sanitation coverage mirrored this growth with access rates at 52% of the population in 1990 growing to79% coverage by 2010 (UNICEF and WHO, 2013). Due to these high rates of reported access, this area is well suited for post-implementation evaluation. This research was designed to allow comparison between current levels of access in a region and the overall country-wide statistics. Additionally, the current status and access of water and sanitation facilities in three communities in the Delta was analyzed. In addition to investigating the usage and status of facilities, relationships between household characteristics and water and sanitation access were explored. Limitations of current development strategies for water and sanitation that can contribute to future strategies in a post 2015 development agenda were identified and examined.

3.3 Methods

Data from southern Vietnam were collected through cross-sectional sampling in three villages in the Vietnamese Mekong Delta. Interviews with key officials, household surveys, and water quality samples for microbial and other analyses were completed.

3.3.1 Site Description

Villages within the An Phu, Tri Ton, and Bunh Thuy districts were selected for this study to represent different risk levels to sea level rise (SLR), flooding, and socioeconomic conditions of the delta (**Figure 3.1**, Table 3.1). As shown in **Figure 3.1.A**,

the Vietnamese portion of the Mekong Delta is dominated by agricultural and aquaculture land use. The village selected near An Phu (village 3) resides furthest north in the Mekong Delta in an area that borders Cambodia and experiences highly seasonal flooding. The village selected near Tri Ton while also northern, is closer to the Gulf of Thailand (village 1). Finally, the village near Binh Thuy is the furthest south and most urban of the three areas village 2). The village names have been omitted to protect the anonymity of respondents, particularly the local authorities interviewed.

The vulnerability to sea level rise was assigned to each village based on the results of the predictive model by Wasserman *et al.* (2004), which used historic and simulated hydrologic gauge data and two different sea level rise scenarios. As shown in **Figure 3.1B**, Wasserman *et al.*(2004) defined three zones of vulnerability relating to sea level rise. This work utilized the Vietnam River Systems and Plains model which calculated flow and flooding regimes and integrated sea level rise predictions. The vulnerability was defined by computing the ratio of water level rise to sea level rise in order to gauge the relative impact triggered by sea level rise with three ratio output categories: high ($x > 0.66$), medium ($0.66 > x > 0.33$) and low ($x < 0.33$). Village 1 is located in the medium vulnerability band, village 2 is located in the high vulnerability band, and village 3 is located in the low vulnerability band. Although all three villages are susceptible to flooding during a moderate flooding event (**Figure 3.1C**), they are exposed to different levels of risk, classified by vulnerability to flooding.

Vulnerability to flooding for each village was classified using multiple sources of data. First, flood depth and duration from 1985-2010 were used to evaluate the current status of flooding in each village (Cambodia-Japan Cooperation Centre, 2013; Mekong River Commission, 2010, 2014). These data indicate that the village 3

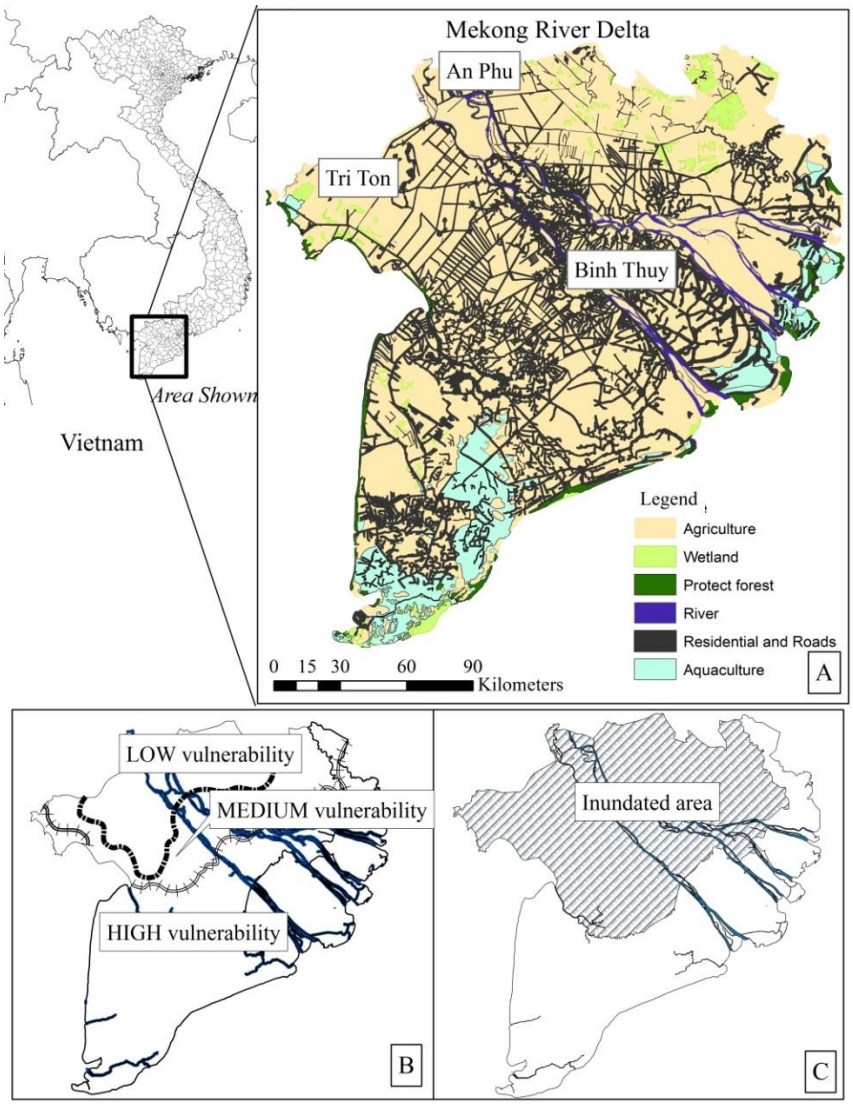

Figure 3.1. Vietnamese Mekong River Delta;
Chart 3.1A, Land Use and Site Locations; Chart 3.1.B Sea Level Rise Vulnerability (Wassmann et al., 2004); Chart 3.1.C Area inundated by a moderate flooding event (Mekong River Commission, 2014)

is most susceptible to flooding, followed by villages 1 and 2. One study which utilized a hydrodynamic model and the flood vulnerability index (FVI) method indicated that the area near village 3 is at a high risk (FVI = 0.6 to 0.8) for future flooding and village 1 is at a medium risk for future events (FVI = 0.4-0.6) (Dinh *et al.*, 2012). In reference to future major climactic events however, village 2 is more susceptible to flooding impacts from southern typhoons and large storms from the South China Sea since it is the most

downstream village of the three and is located on the main stem of the Mekong River (Chaudhry and Ruysschaert, 2008).

Table 3.1. Select socioeconomic and climate variations between each village

Closest provincial town	Village number	Approximate village population	Land area per household	Poverty incidence†	Vulnerability to Flooding*	Vulnerability to SLR**
Tri Ton	1	2,000	12	40-50%	Medium	Medium
Bunh Thuy	2	17,000	0.34	10-20%	Low	High
An Phu	3	11,000	12	30-40%	High	Low

†According to Minot et al., 2003
*Approximated based on average flood depth, average flood duration, climate predictions and major flood events. See above text
**According to Wasserman *et al*, 2004

The three villages selected for this study are surrounded by agricultural areas, with Binh Thuy being the most peri-urban of the three. Water and sanitation development in these communities varied. All three villages had some piped-water coverage provided by a private province-level water utility. All three villages also had at least one large non-governmental organization program or project related to water and sanitation. In village 3 for example, some households had installed latrines using funds obtained in a grant from an international non-governmental organization operating in the town. The exact number of households involved in each type of development intervention remains unclear. Due to the large degree of heterogeneity in water and sanitation installation programs throughout the region, the type of water and sanitation facility, as defined by the UN definition of improved water and sanitation, was used to compare households instead of specific implementing agency or organization. This varied coverage provides a general context for analyzing water and sanitation access in the region, since they represent different village types within the Delta.

3.3.2 Data Collection and Management

Qualitative and quantitative research methods were incorporated as part of a larger study aimed at broadly conceptualizing household vulnerability, as it relates to

water resources now and in the future. The qualitative approaches included interviews with local administrative key personnel including local government officials and leaders and field observations. Field observations included enumerator recording of water and sanitation facility conditions. The field observations and interviews with local personnel informed the design of a structured questionnaire that was conducted using random sampling within each selected community between February and April 2014. The sampling frame was determined through an initial site visit to each community. During this site visit, local administrative personnel provided an aerial map of all households within the village. Then, each household was assigned a number and a random number generator was used to randomly order all of the households. The first 100 households on the randomly generated list were approached for interview and additional households from the list were utilized if one or more household declined to participate in the survey. Of the initial 300, only 2 households declined to participate.

The survey included questions relating to water and sanitation facilities. In addition to asking usage, health, and hygiene questions, the survey enumerators observed and recorded details regarding the facility quality at each household. **Table 3.2** describes the various household characteristics included in this study. These characteristics represent socioeconomic information including the size of the household, number of children in the household, age of respondent, employment, and education level. Variables were chosen based on previous studies related to water and sanitation. On a country-wide scale, economic resources have been shown to be significant predictors to sanitation coverage (Fry *et al.*, 2008). In order to represent variables relating to income and household wealth, this study included owning livestock, a motorbike, household materials, and education levels. Utilizing variables relating to ownership of goods and education have been commonly implemented in similar studies (Günther and Fink, 2010; IFC International, 2014). Additionally, since it is widely reported that more rural households are less likely to have access to water and sanitation (UNICEF and World Health Organization, 2014) two questions regarding the household distance to the local government office and the local market were recorded.

Table 3.2. Independent variables gathered through household survey

Variable Name	Variable Description	Measure
Village	Village of respondent	Categorical (e.g. Village 1, Village 2, Village 3)
Household Size	Number of people in household	Continuous
Children in household (<18yr)	Number of children under 18	Continuous
Children under 5yr	Number of children under 5	Continuous
Age	Age of respondent	Continuous
Agricultural Employment	Primary income generator is agricultural in nature (e.g. Harvesting, planting, fishing)	1 if agricultural employment, otherwise 0
Education Level	Highest level of diploma achieved by respondent	Continuous
Local Government	Distance to local government office	Continuous
Local Market	Distance to local market	Continuous
Food Security	Respondent identified experience in food shortage over the past year	1 if experienced food shortage, otherwise 0
Water Manager	Respondent identified water manager for household	1 if Female, otherwise 0
Hand washing	Respondent identified number of times hand washing occurs throughout the day	Continuous
House size	Respondent identified house size (ha)	Continuous
Farm size	Respondent identified farm size (ha)	Continuous
Household floor material	Enumerator observation of household floor material	Two binary variables: 1 if wood floor, otherwise 0; 1 if Dirt/Earth floor, otherwise 0
Household wall material	Enumerator observation of household wall material	Two binary variables: 1 if wood floor, otherwise 0; 1 if Dirt/Earth floor, otherwise 0
Household roof material	Enumerator observation of household roof material	One binary variable: 1 if thatched/woven, otherwise 0
Motorbike	Respondent identified ownership of motorbike	1 if yes, otherwise 0
Livestock	Respondent identified ownership of livestock	1 if yes, otherwise 0

Since the MGDs specifically target and track childhood mortality, this survey included recording the number of children under 18 as well as the number of children under the age of 5. Additionally, recording who manages the water in each household provides insight into the roles of women as water managers and if this influences the likelihood of household water access. International development has recognized the importance of women in water and sanitation development (Rahaman and Varis, 2005; Ray, 2007); however, their level of importance has yet to be quantified. Finally, a unique variable that is not often analyzed in conjunction with water and sanitation studies is household food security. Through this survey respondents were asked if they had experienced not having enough to eat within the past year in order to informally measure food security.

Also included in two of the three models was the opposite technology of the dependent variable under consideration. For example, in the sanitation regression model, the households with access to improved water were recorded as a binary response 1, while households without access were represented by 0. Finally, the household wall, floor, and roof material questions also included an "other" choice outside of wood and dirt-earthen.

3.3.3 Statistical Procedures

After data collection was completed, survey responses were coded using R statistical software. The categorical responses were dummy coded to allow interpretation through regression modeling. Utilizing binary logistic regression, the survey responses were tested to quantify the strength of relationships between access to water and sanitation (yes or no) and the other household characteristics. This procedure was chosen after frequency Chi-Squared testing revealed that the responses between households with access and households without access were significantly different from one-another. Other methods such as traditional ANOVA procedures are not well suited for this investigation because survey responses, particularly from categorical questions, are not easily interpreted through the analysis of means. Three binary regression analyses were then performed to complete the key objective of jointly examining the effects of variables on households with access and without access to improved water and sanitation. The

three regression models analyzed: 1) All households with access to improved water, 2) all households with access to basic sanitation, and 3) households who had access to both improved water and sanitation facilities.

3.4 Results

3.4.1 Household Access

Of the households surveyed, roughly 73% had access to improved water and sanitation facilities (**Table 3.3**). Although the access percentages were nearly identical between water and sanitation, there was some variation between households with access to sanitation, water, both, or neither.

Table 3.3. Current coverage of improved and unimproved water and sanitation facilities

		N	Percent
Sanitation	Improved	221	73.7%
	Unimproved	79	26.3%
Water	Improved	220	73.3%
	Unimproved	80	26.7%
Households with both improved sanitation and water		175	58.3%
Households with either improved water or sanitation		91	30.3%
Households with neither improved sanitation or water		34	11.3%

The types of facilities each household had also varied among participants. As shown in Table 3.4, the most common "improved" technologies for sanitation and drinking water included flush/pour toilets and piped facilities, respectively.

Access to improved sanitation among the households that participated in this study was similar to improved water access reported by the United Nations (UNICEF and WHO, 2014). Access to improved water was lower than reported previously for this area (UNICEF and WHO, 2014). This could be due to the general consensus that country level reported values are most likely over estimating access to water and sanitation due to

disrepair, failure of technologies, lack of acceptable use in communities, and the lack of continued monitoring within many countries (UNICEF and WHO, 2014).

Table 3.4. Type of water and sanitation facilities among households

	Type of technology	N	Category
Sanitation	Flush/Flush pour	129	Improved
	Ventilated Pit Latrine	35	Improved
	Simple pit with cement slab	57	Improved
	Open Pit	16	Unimproved
	Latrine over ditch	16	Unimproved
	No facility, brush, bag,	47	Unimproved
Drinking water	Piped water	179	Improved
	Rainwater	13	Improved
	Borehole/Well In Yard	16	Improved
	Borehole/Well Shared	12	Improved
	Bottled water with unimproved	3	Unimproved
	River water	77	Unimproved

3.4.2 Binary Logistic Regression

Households were compared for differences in responses to key measured variables and whether the household had access to either water or sanitation. These were measured as covariates in an analysis of possible correlations between the dependent variable (access to water, sanitation, or water and sanitation) and the independent variables (household characteristics, food security, water management, *see table 2*). Table 3.5 and Table 3.6 illustrate the model outputs, which indicate that many of the variables considered for interpretation significantly influenced the access to water or sanitation. The odds ratio describes the relative measure of effect of the independent variable which was calculated by taking the natural logarithm of the regression coefficient. An odds ratio greater than 1 is associated with higher odds of a household having access to water or sanitation while an odds ratio of less than one indicates that variable contributes to a lower odds of having access to water or sanitation. Of the variables that were insignificant, the education level and the age of respondent present an interesting contrast to previous literature (Günther and Fink, 2010). Utilizing 172 Demographic Health

Surveys, Günther and Fink (2010) found that the education level of the mother in each household was significantly correlated to several different water and sanitation related dependent variables including childhood diarrhea, child mortality, and technology type of water and sanitation intervention. Although the data is not exactly comparable because the education level recorded on this survey was based on the respondent, which was not always the mother, it still provides interesting insight into the influence or lack of influence that household education levels have on various aspects of access to water and sanitation.

Household characteristics that demonstrated significant relationships between survey responses and access to water or sanitation included the distance to a government office (for sanitation model) and distance to the a local market (for water model). When the households with access to both water and sanitation were examined, the distance to a local government office was not only significant but the odds ratio was less than 1, indicating that closer the household was to the government office the more likely they were to have access to both water and sanitation facilities. This interpretation indicates that the closer a household is to a government office, the greater the odds of having access to sanitation. Conversely, these results suggest that the further a household is from a market, the greater the odds of having access to an improved water source.

Women water managers have been heavily studied in the literature as a key factor in success and these results support that claim. As shown in Table 5, households that had a woman managing their water supply were three times more likely to have access to improved drinking water than those households who did not have a female water manager. Another interesting finding relates to the home and farm sizes of these households. For both access to water and access to both water and sanitation, a larger home size significantly increased the odds of having access, yet the larger farm size decreased the odds of access. Food security was a significant predictor of access to sanitation but not access to water. Respondents who indicated they had experienced not having enough to eat were approximately 70% less likely to have access to sanitation facilities.

3.5 Discussion and Conclusion

Several household characteristics including respondent age, household size, and level of education provided contrast to results found in other studies (Günther and Fink, 2010), several of these findings present further contribution to the current literature on the generalizability of variables that influence access to water and sanitation. In the study by Günther and Fink, many household characteristics were correlated to the water and sanitation dependent variables including education of the mother, age of the mother, and household wealth as measured by ownership of a radio, tv, fridge, or bike. In contrast, these results found no significant correlation between education level or ownership of a motorbike and livestock. Additionally, household size was not significantly correlated in the Günther and Fink study, which mirrors the results found for this sanitation regression model but not for the drinking water model. This may indicate that neither specific water and sanitation health outcomes (Günther and Fink, 2010) nor sanitation facility type are significantly coorelated to household size. Fry *et al.* (2008) found that income groups are significantly correlated to percent of sanitation coverage. Using household building materials and ownership of livestock and a motorbike as indicators for income, these results do not support those of Fry *et al.* with regard to drinking water access.

Houses made of wood, most of which were traditional Vietnamese stilt houses, had significantly lower odds of access to sanitation. While these houses are well suited to manage water when annual flooding occurs, they also appear to limit the ability of households to implement and install sanitation facilities. Additionally, reports from the JMP have pointed to disparities between urban coverage and rural

Table 3.5. Binary Logistic Regression

Variable Category ***Significant at 10%, ***Significance at 5%**	Access to Sanitation		Access to Drinking Water		Access to Both Water and Sanitation	
	Odds Ratio	z-statistic	Odds Ratio	z-statistic	Odds Ratio	z-statistic
Village 2 (Village 1 as Reference)	2.454	1.37	0.715	-0.57	1.224	0.37
Village 3 (Village 1 as Reference)	0.434	-1.44	1.372	0.51	0.721	-0.62
Water or Sanitation	1.923	**1.71***	1.749	1.38	-	-
Household Size	1.125	0.94	0.940	-0.50	0.939	-0.58
Children in household (<18yr)	1.317	1.09	1.506	1.46	1.450	**1.65***
Children under 5yr	0.787	-0.80	0.437	**-2.75*****	0.607	**-1.97*****
Age	1.009	0.69	0.984	-1.22	1.003	0.25
Agricultural Employment	1.129	0.32	0.872	-0.37	1.135	0.37
Education Level	1.313	1.52	1.243	1.35	1.276	**1.81***
Local government	0.876	**-2.91*****	0.941	-1.25	0.911	**-2.26*****
Local market	0.950	-0.85	1.119	**1.79*****	1.007	0.13
Food security	0.305	**-3.33*****	1.092	0.23	0.428	**-2.69*****
Water manager	0.795	-0.58	3.043	**2.95*****	1.616	1.39
Hand washing	0.987	-0.30	1.028	0.60	1.047	1.16
House size	1.271	0.16	4.422	**2.01*****	8.674	**2.31*****
Farm size	0.867	**-2.16*****	0.891	**-1.74***	0.776	**-2.40*****
Household floor material- Dirt/Earthen	0.383	-0.78	1.771	0.61	0.377	**-2.10*****
Household floor material- Wood	0.306	**-2.27*****	0.360	-2.09	0.907	-0.16
Household wall material- Dirt/Earthen	0.350	-1.48	2.571	0.08	0.622	-0.37
Household wall material- Wood	0.376	**-2.09*****	0.568	-1.29	0.412	**-2.35*****
Household roof material- Thatched	0.631	-0.52	2.218	0.62	1.157	0.16
Motorbike	1.723	1.14	1.169	0.31	1.494	0.90
Livestock	1.295	0.78	0.706	-1.01	1.011	0.04

Table 3.6. Regression summary statistics

	Sanitation Model	Water Model	Combined Model
Number of observations	300	300	300
Log likelihood at null	-131.333	-127.86	-162.5754
Chi-Squared significance	<0.0001	<0.0001	<0.0001
Adjusted R^2 value	0.354	0.38	0.323

coverage, indicating that living farther away from an urban area decreases the likelihood of coverage (UNICEF and WHO, 2013, 2014). The work described herein included measurements of the distance from households to two important local destinations, the local government office and local market. With the sanitation results, these data support the conclusions drawn by the JMP; however, these data refute the relationship for improved water access showing that living farther away actually increased the likelihood of access to improved water. This may indicate that the government and non-governmental organizations working in Vietnam have successfully focused on rural household drinking water access. Overall, this study confirmed several factors that contribute to water and sanitation access that mirror factors identified in previous literature as well as contradict previous factors which indicates that providing access to water and sanitation is not as simple as one would hope.

The results of this work could be used to further target households within the region that still do not have access to water and sanitation facilities. For example, organizations working throughout this region should target sanitation access to populations living in traditional wooden stilt houses. Additionally, agencies continuing to address access to improved drinking water may choose to target households with children under the age of five. Finally, food insecure families are much less likely to have access to sanitation facilities so programs addressing either food availability or sanitation access may be able to target the same population to accomplish increasing food security and access to basic sanitation simultaneously which could be more resource and cost effective. By analyzing access to improved water and sanitation coverage simultaneously, it is possible to identify factors that affect one intervention and not the other.

As the target year for completion of the MDGs has arrived, it is imperative to continue bringing water and sanitation interventions to people worldwide. Despite the

general success in reaching the drinking water MDG, there is much work to be done with regards to sanitation access. This study indicates that the factors influencing sanitation do not mirror those influencing drinking water and ought to be considered separately. Although water and sanitation are intricately entwined, these results suggest that more tailored approaches by the international community will be necessary to continue development success in the coming decades.

CHAPTER 4. INDEPENDENT ASSESSMENT OF THE CHALLENGE PROGRAM ON WATER AND FOOD: AN ANAYLSIS OF THE ATTITUDES AND PERCEPTIONS OF PARTNER ORGANIZATIONS

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4.1 Background

The CGIAR is an international organization that includes 15 research centers which advance international agricultural research to work toward a more food secure world. The CGIAR has carried out numerous comprehensive independent evaluations and several case study review papers that summarize impacts of research for development programs or interventions within the international research community. Renkow and Byerlee (2010) developed a review of all CGIAR impact studies done between 2000 and 2010. Based on these reviews, they concluded that CGIAR impacts the global community and works towards relieving food insecurity by measuring outcome oriented criteria, such as impacts on yields and poverty reduction.

One limitation of these evaluations was that there has been lack of assessments of the CGIAR impact on resource management and policy (Renkow and Byerlee, 2010). In addition, many other cases show impacts through tools such as economic evaluations, theories of change stories, and benefit-cost assessments (Horton, 1986; Templeton and Bayot, 2011; Mayne, 2011; McDonald, 2011). In the 1990s, CGIAR also implemented a protocol for reviewing each of the 15 research centers every five years which includes evaluating the quantity and quality of research, research results, management efficiency,

strategic directions, impact, and science quality (Anderson and Dalrymple, 1999). Reviews of the research centers usually involve visiting center locations, field sites, and interviewing partners, but do not include specifically measuring impacts of projects like the cases specified previously. Despite the wide range of frameworks and impact assessment theories, these methods focus on evaluation of a specific intervention or program and do not define implications for the overall effectiveness of a research for development (R4D) organization. Current impact assessments have limitations due to their linear input-output assumptions, which is not the way most innovative R4D organizations function (Maredia et al., 2000; Hall et al., 2003). Additionally, these impact studies often improperly link research dollar expenditures to impacts without factoring other potential influences (Ekboir, 2003).

The innovation systems framework developed by Hall et al. (2003) shifts the focus of impact and evaluations, which tend to examine a change in a particular technology and the associated user groups, to include changes in the way the research community operates and interacts with one another. These researchers also stressed the value of recognizing capacity development as an important research outcome (Hall et al., 2003). Another framework that allows for the inclusion of multiple program facets is a comparative framework that includes both process and outcome oriented criteria (Mog, 2004). In 2008 an Independent Review Board conducted a survey analysis of partners and stakeholders of the entire CGIAR system to determine how well positioned CGIAR is to tackle emerging issues in food security throughout developing countries based on partner perceptions and attitudes (McAllister, 2008a). This study articulated the significant importance in partnerships for CGIAR centers to be effective and relevant (McAllister, 2008b).

To contribute more to institutional learning and change through program evaluation, several studies have suggested using innovation system frameworks, draw on multiple sources of evidence, use a variety of disciplines, and do not focus solely on achievements that can be easily measured (Ekboir, 2003; Horton and Mackay, 2003; Mog, 2004; Hall et al, 2003).

This chapter presents looks at the findings of a study which sought to measure the attitudes and perceptions of people who are formal and informal partners with the

Challenge Program on Water and Food Mekong (CPWF-M). The program stemmed from an initiative of the CGIAR which focused on six well-defined eco-regions, one of which was the Mekong Basin. The CPWF-M occurred in two distinct phases. During Phase 1, CPWF-M managed 13 R4D projects. An additional 19 projects were implemented during Phase 2, which totaled $10.7 million in investments. In addition to these research projects, CPWF-M held a variety of networking events including the Annual Forum on Water, Food and Energy in the Mekong Basin where researchers, non-profit organizations, private companies, and government agencies can come together to talk about threats and challenges to water management and provisioning in the Mekong Basin.

To study the attitudes of partners of CPWF-M and the regional network as a whole, both quantitative and qualitative measures were applied. An online survey (Appendix C) and interviews of partner organizations took place between June 2013 and November 2013. In combination, these measures serve to illustrate the impacts of CPWF-M, from the perspective of partnership accountability.

4.2 Introduction

4.2.1 Survey Sampling Frame and Response Rate

Several versions of an online survey questionnaire were developed and reviewed with staff members from the CPWF-M in April and May 2013. The final version was then developed and sent via email to the contact list of formal and informal partners provided by CPWF-M. Participants were ensured of confidentiality to elicit the most free and honest answers. Formal partners included those who have an official memorandum of understanding or similar endorsed document which articulates the collaboration, while informal partners consist of organizations working with CPWF-M without an authoritative collaboration document. They were also given the option to not complete any question they felt uncomfortable with or were unwilling to answer.

Although it was known that many of the respondents were native to the countries in the Mekong River Basin and therefore spoke English as a second language, the survey was written and conducted in English. English was chosen because it is the language of communication used throughout the development community within non-profits, for

profit companies, and government organizations in the Mekong Basin. English is also the official language of the Mekong River Commission.

An initial list of 101 email addresses, which represented 89 different partner organizations, was used for the first round of emailing. Three email addresses were found to be invalid and were not contacted in future email reminders. Two weeks after the initial email was sent to prompt responders, a second email reminder was sent. Additionally, a third and final email reminder was sent one month after the initial mailing. Survey results were recorded using the software Qualtrics. The overall response rate was 59% (n=58). The distribution of survey respondents spanned multiple types of organizations as well as various scales of organizational scope. Table 4.1 shows the respondent distribution for seven different types of organizations. These types were established to view the survey through the perspective of different organizational types. Of the 58 respondents, 15 chose not to disclose the organization for which they worked, and were therefore considered to be "undisclosed".

Table 4.1. Organization Type of Survey Respondents

Type of Organization (Org.)	**Number of Respondents**
Research Org.	7
Non-profit Org.	9
Private Corporation	5
University	9
Government Institution	10
CGIAR	2
Network/Advocacy Org.	1
Undisclosed	15
Total (n)	**58**

Table 4.2 indicates the geographic scope of the organizations that responded to the online survey. It should be noted that scope was defined in a very broad sense and is not necessarily indicative of all of the organizations' activities within the Mekong Basin. For example, non-governmental organizations that were based in a country other than those within the Mekong River Basin were considered to be global organizations, even if their regional office only dealt with regional projects. In addition, to remain consistent,

governmental organizations for countries within the Mekong Basin were defined as local or regional, while governmental organizations from countries outside of the Mekong Basin were always defined as global. Table 4.2. Geographic Scope of Survey Respondent indicates a range of different organizations with regards to geographic scope as well as type.

Table 4.2. Geographic Scope of Survey Respondent Organizations

Geographic Scope of Organization	Number of Respondents
Local	20
Regional	10
Global	13
Undisclosed	15
Total	**58**

In addition to the online survey, in-person interviews were conducted with 15 in-country representatives of partner organizations of CPWF-M in Vientiane, Laos June 2013. In November 2013, an additional eight representatives of partner organizations were interviewed in Hanoi, Vietnam for a total of 23 in-depth interviews. These interviews focused on organizations that have directly interacted in a formal collaboration with a CPWF-M project. Interviews took place in a location chosen by the interviewee and ranged in length from 45 minutes to 2 hours. To examine potential themes generated through these interviews, the text transcriptions and interview notes were coded using NVivo 10 software.

4.2.2 Overview of Questions

The questions analyzed from the online partner survey included multiple choice, Likert scale, and open response questions. Table 4.3 summarizes the variety of questions analyzed from the partner survey. These questions included both process and outcome-oriented criteria relating to research priority areas and outputs, partnerships, and networking activities. Results from the qualitative data were analyzed using common statistical techniques for categorical data with the R computational software.

Table 4.3. Questions analyzed from the online partner survey

• Use 1-5 Likert rating scale to evaluate if CPWF-M:
o Facilitates discussion o Brings nontraditional actors together o Is a powerful networking initiative in the Mekong Basin o Is important in the future
• Use 1-4 Likert rating scale to evaluate if CPWF-M has:
o Asked about respondent's priorities in the Mekong o Asked for respondent's knowledge in the Mekong o Incorporated respondent's knowledge into CPWF projects, reports or research design
• Multiple Choice Questions about:
o Most critical environmental and livelihood threats in the Mekong o Preferred and most common methods of communication o List of partnerships and interactions other than with CPWF-M o Attendance at the Mekong Forum on Water and Food o Successes and Improvements for CPWF-M [text entry]

In addition to this online partner survey, interviews were conducted in order to expand on several themes. The interviewees were asked how, when and why they began interacting with CPWF-M. Interviewees were also asked to describe their level of interaction with CWPF-M. Additionally, discussions about the CPWF-M research priorities and outcomes took place. Most of the interview period was spent discussing the successes and limitations of the CPWF-M program and potential avenues for future work within the basin.

4.2.3 Scope and Limitations of the Review

This review was designed to serve as a glimpse into the perspective of partners of the CPWF-M. It was not a review of the outputs from each of the various research projects undertaken by CPWF-M throughout the past decade. A detailed review of that scale would require an extensive team and substantial financial support to complete. An instance that illustrates this limitation in a broad sense relates to environmental

governance. For example, one limitation discussed relates to the lack of CPWF-M involvement in governance work. While this was identified by several respondents as a weakness of the program, CPWF-M has in fact had several specific projects relating to environmental governance. This therefore does not describe a complete lack of work relating to governance, it points to a potential weaknesses in information dissemination and communication on the part of CPWF-M.

This review did not include any baseline or previous data that could be used to measure changing perspectives of CPWF-M over time. The online survey was conducted just once, within the final year of the CPWF-M program. Also, the interviews allowed the collection of information about the current perspectives and attitudes of partner organizations and did not address changes over time or historical opinions relating to this organization.

The scope of this review included quantitative measures of success relating to a few process- and outcome-oriented metrics. Additionally, qualitative data relating to both process and outcome-oriented measures of CPWF-M added to the project narrative. Overall, this review was meant to address the following evaluation questions focusing on the perspective of partner organizations:

1. What are the perceived successes of the CPWF-M program?
2. What are the perceived limitations of the CPWF-M program?
3. What aspects of the CPWF-M program have been useful to the [respondent's] organization?
4. What is the scope and extent of CPWF-M programs within the hydropower community throughout the region?
5. What are the perceptions of the research priorities and outputs from CPWF-M projects?
6. What are the perceptions of CPWF-M partnerships and networking activities throughout the region?

Within each section, results from the quantitative online survey as well as the qualitative interviews are presented. The two key mechanisms for working within the defined framework for research and development efforts, as identified by CWPF-M, include partnerships and producing research that has development relevance and impact (CPWF,

2013). To mirror these mechanisms, this chapter will focus on three themes within these two mechanisms: 1) Research priority areas and outputs; 2) Partnerships between CPWF-M and other organizations; and 3) Networking activities facilitated by CPWF-M. The theme relating to research priority areas and outputs mirrors the mechanism relating to producing relevant and impactful research. The other two themes are directly related to the key mechanism of partnerships. Finally, an outlook on future activities throughout the Mekong River Basin and with specific regards to CPWF-M and broader impacts will be presented.

4.3 CPWF-M Research Priority Areas and Outputs

4.3.1 Useful and Usable Information

To understand the research needs of stakeholders in the Mekong River Basin, this review utilized several different measures intended to evaluate both CPWF-M research efforts as well as research gaps within the basin as a whole. It is important for research for development efforts to produce both useful and usable information. Survey respondents were asked to identify the most significant threat to the Mekong Basin in terms of both environmental sustainability and the sustainability of the livelihoods of Mekong citizens. This information served to confirm past work relevance and inform future research topics. As shown through Figure 4.1 **Threats in the Mekong BasinFigure 4.1**the largest number of respondents believe large-scale infrastructure projects such as dams are the greatest environmental threat. The two topics that threaten the livelihoods of citizens in the Mekong Basin are governance and large scale infrastructure projects. While the overall goals of CPWF-M deal directly with managing large scale infrastructure projects, many respondents agreed that governance issues throughout the basin are equally as important.

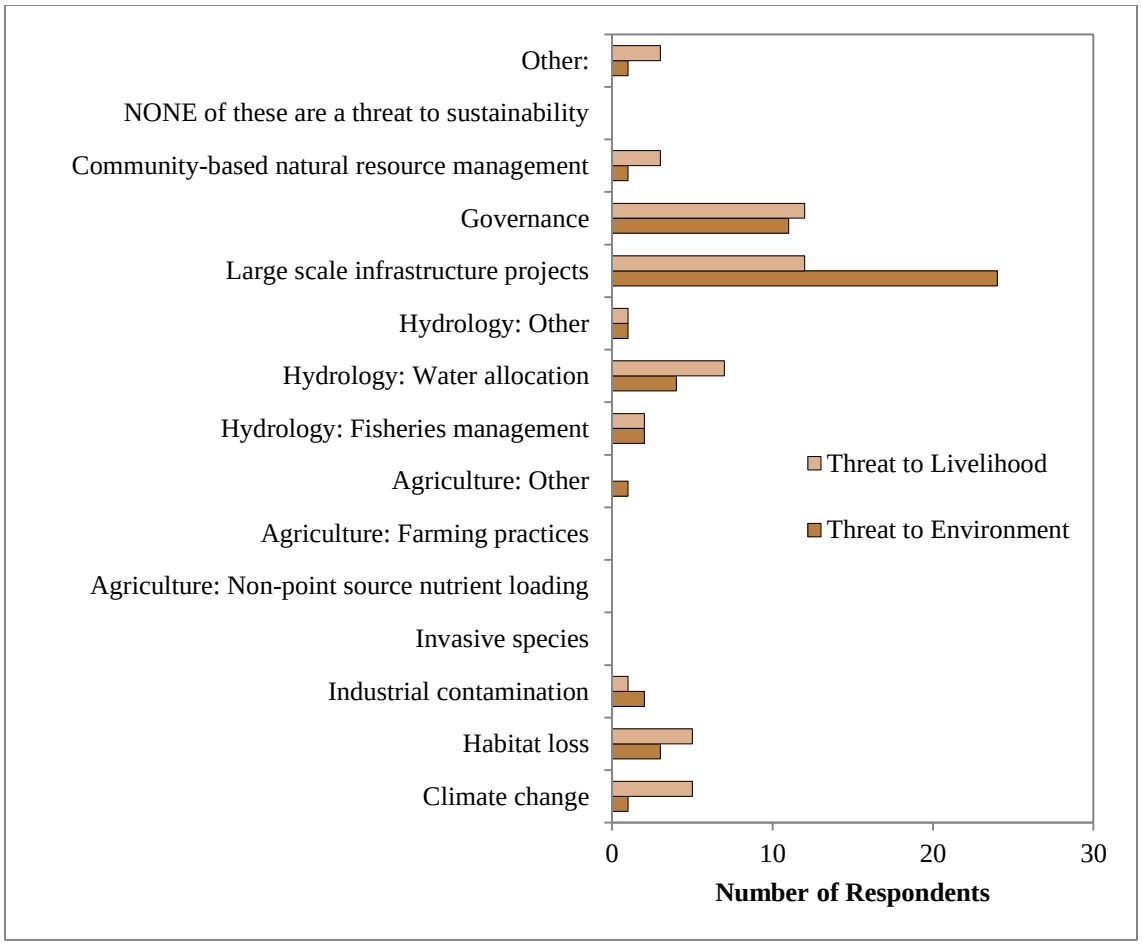

Figure 4.1 Threats in the Mekong Basin

Often, credible research is only disseminated through peer reviewed journal articles. While these are useful for academic pursuits, they can be difficult to access for practitioners and policy makers alike, particularly in the field of international development. Additionally, because of strong demands for transparency, and multitude organizations working in the field of international development, information overload is a noteworthy issue. To evaluate which communication channels CPWF-M partner organizations preferred to receive information about the Mekong Basin, two questions were asked. These questions, as summarized by **Figure 4.2**, asked respondents to identify their most preferred method and most frequent method for receiving scientific information. Each respondent was asked to choose two methods.

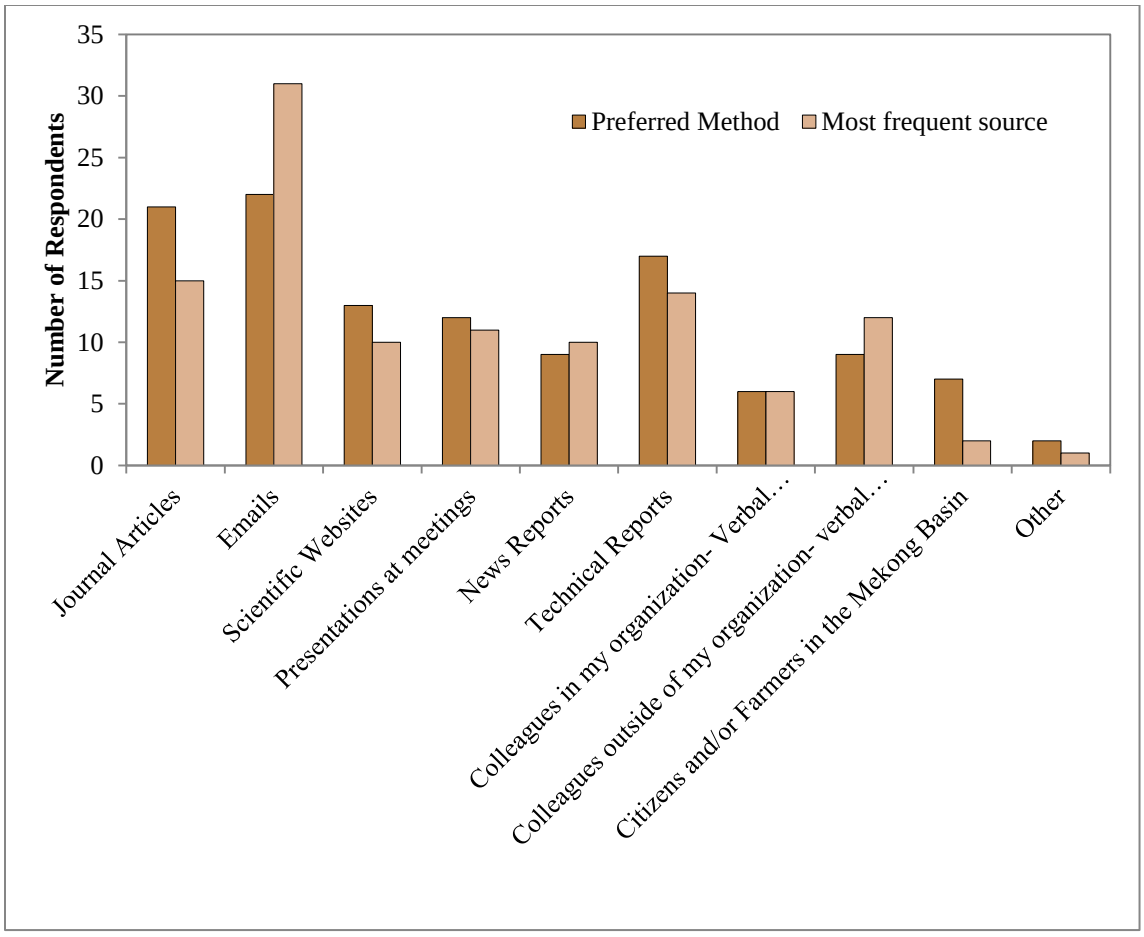

Figure 4.2. Preferred and most common method for receiving scientific information

CPWF-M has utilized a variety of output dissemination methods. Reports and lists of journal articles are available on the CPWF-M website, it has held numerous events to disseminate results, the most noteworthy including the annual Mekong Forum on Water, Food, and Energy. Phase 1 projects spanned a variety of topics and focus areas and Phase II results had not yet been disseminated at time of review.

Three 1-4 Likert scale questions were asked relating to respondents perceptions of CPWF-M incorporation of stakeholder knowledge. These areas relate directly to the Coordination and Change project, which intended to connect the efforts of multiple CPWF-M Phase II projects as well as disseminating results of various efforts. The CPWF-M program utilized the Multi-Stakeholder Platform approach which has been shown to integrate knowledge from stakeholders to articulate knowledge and yield sustainable outcomes (CPFW-M, 2013; Warner, 2006; Warner, 2007). This participatory management strategy, when implemented well, can ultimately generate both relevant and

impactful results. As shown through Figure 4.3, survey respondents showed overall positive perceptions on the three questions relating to CPWF-M participatory efforts to learn and utilize knowledge from partner organizations. The highest rated response showed that CPWF-M partners believed the program had incorporated their knowledge into research reports and outputs of the program. The lowest ranking stemmed from the question regarding whether or not CPWF-M had asked each partner about the partner's priorities in watershed management within the Mekong Basin. This question still yielded 60% of participants who responded positively.

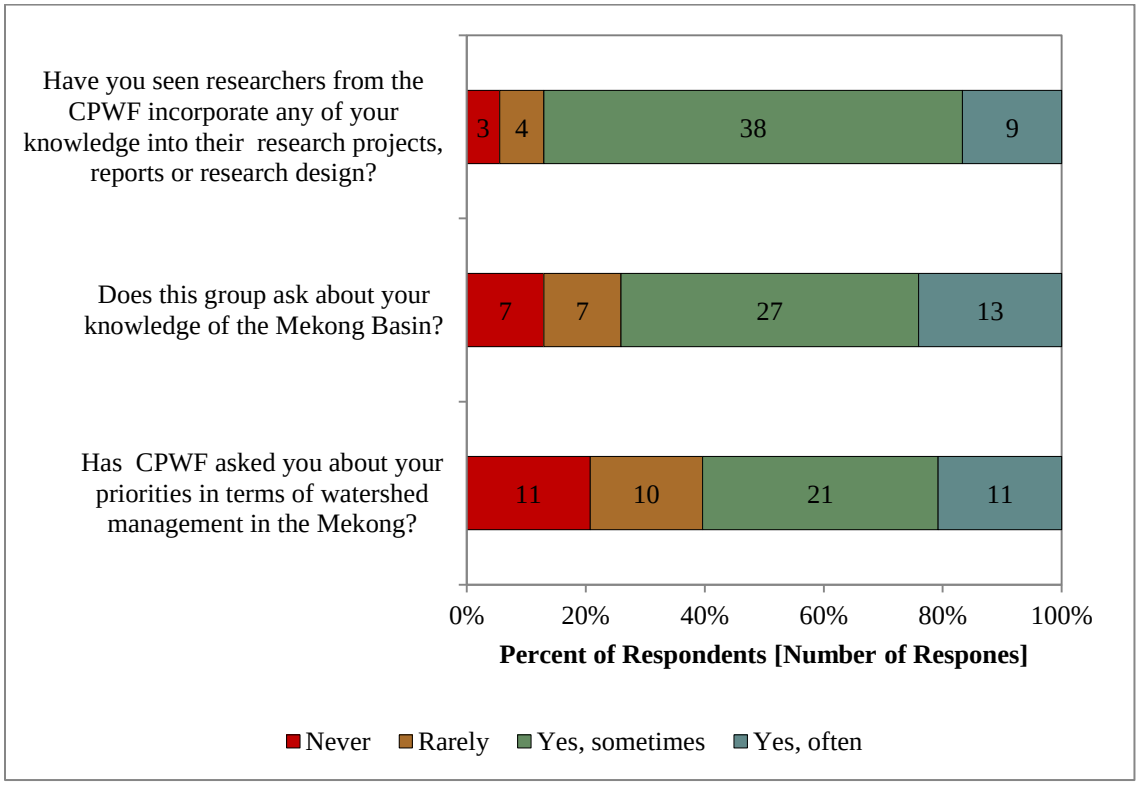

Figure 4.3. Participant ratings of three questions relating to participatory management

Although these questions have relevance to one particular Coordination and Change project implemented by CPWF-M , they should not serve as direct ratings of that project. Survey respondents included partners who have been involved in many aspects of CPWF-M programs throughout the ten years. Therefore, it is possible that survey respondents were not involved in any aspect of the Coordination and Change project. Many of the survey respondents were involved in Phase II projects that occurred after the implementation of the Coordination and Change project. These results however, still have

relevance to partner perceptions of CPWF-M efforts to facilitate participatory water management throughout the basin.

4.3.2 Issues and Respondent Comments

The most frequently re-occurring theme related to research priority areas and usable and useful outputs was the CPWF-M role in policy decisions throughout the basin. The transparency of hydropower decisions made by government agencies and private companies throughout the Mekong River Basin has been a point of contention in the recent past (Molle et al, 2009). Based on discussions with CPWF-M partner organizations, as well as the qualitative responses from the online survey, many respondents believed thatCPWF-M has not had a meaningful impact on these governance issues. CWPF-M has specifically targeted several environmental governance projects, but partners either did not know about these efforts or did not see them as adequate progress in the area of political governance. There were six people from the online survey who believed that the CWPF-M research efforts and programs were not applicable to policy within the basin. In addition, another four respondents believed that even if the research efforts were applicable, CPWF-M could not influence policy makers. Several respondents also believed that the whole idea of sustainable hydropower was a myth that made CPWF-M outputs on the subject unusable to those specific respondents.

Regardless of the intentions of CWPF-M, the survey results as well as the themes derived from interviews pointed to a large group of CPWF-M partners who wished CPWF-M had more influence in policy decisions on a basin level. These expectations are difficult to meet in the ten year timeframe of this program. It is important to note, as one interviewee articulated, that it is difficult for any type of research and development program to have meaningful policy influence within the Mekong Basin because the pace of hydropower decisions and rate of change in infrastructure projects are much faster than the rate of traditional research and development dissemination efforts. Additionally, long-term outcomes from CWPF-M efforts may not be completely understood until after program completion.

Outside of the policy debate, it also became clear that many of the physical CWPF-M research outputs have yet to be fully utilized within the Mekong River Basin.

In discussing research outputs such as research reports, journal articles, maps and other resources, very few of the interview respondents had utilized any of these. In Phase I, CPWF-M produced numerous reports and journal article publications based on the results of research for development activities. These results were not, however, being currently used by any of the partner organizations who were interviewed. Additionally, Phase II results, which had a variety of practical research endeavors, have yet to be fully disseminated. There were a few respondents who did discuss the basin-wide hydropower map, which pinpoints locations of existing, under construction, and planned dams as a highly successful output. Many of the Phase II results have been published since the completion of this study; their relevance and impact have not, however, been evaluated.

The online survey and interviews also provided a variety of research topics that could be implemented in future research and development efforts throughout the basin (Table 4.4. Mekong River Basin Research Gaps**Table 4.4**). Additionally, most respondents from both the online survey as well as interviews pointed to some aspect of CPWF-M efforts in capacity building, partnerships, and networking activities as successful outputs for the ten-year program. These specific outcomes will be discussed in the following sections.

Table 4.4. Mekong River Basin Research Gaps

The most commonly identified areas of research where respondents would like to see more work included:

- **Agricultural research including**: Irrigation plans for MRB countries and how they relate to hydropower operations and best management practices for farming techniques and livelihood development projects that can be shared and applied in other contexts.
- **Political and social research including**: Studying the decision-making processes for water management, including hydropower and performing socioeconomic impact studies on communities affected by infrastructure development.
- **Water resources research including**: work on sedimentation, altering water flows, fisheries safety, and climate change impacts.
- **Integrated research including**: ecosystem services valuation of natural resources throughout the MRB, multiple sector links at the regional level, and cumulative impact assessments of major management decisions.

4.4 CPWF-M Partnerships

The second of the two key mechanisms for CPWF-M was working through partner organizations. An analysis of partner organizations as well as networking themes, though intrinsically linked, has been separated for detailed examination in each of the following two sections. CPWF-M documents were used in conjunction with the partner survey results and in person interviews to construct the lessons learned from the CPWF-M partnership evaluation.

4.4.1 Diversity of Formal and Informal Partners

As a part of this analysis, a list of formal and informal partners was provided in June 2013 to the researcher. This list was utilized for the analysis of formal and informal partners. The partnerships identified 89 distinct entities with relationships to CPWF-M. Several notes should be made to indicate the details of this partnership analysis. First, the 89 different entities do not indicate 89 different organizations. This is due to the fact that CPWF-M sometimes has partnerships with different autonomous parts within the same organization, for example, more than one department within the same university. Additionally, this list does not include all of the countless people and organization representatives that may have attended one or more of the many networking and community events throughout the 10 years of CPWF-M. Most of these partners have worked in one part or another on some aspect of a project relating to either Phase I or Phase II of the CPWF-M program.

As shown in Figure 4.4, CPWF-M built partnerships with a variety of different types of organizations. These included both formal and informal partnerships. These data indicate that CPWF-M facilitated partnerships with a variety of international, regional, and domestic organizations, as well as several types of organizations.

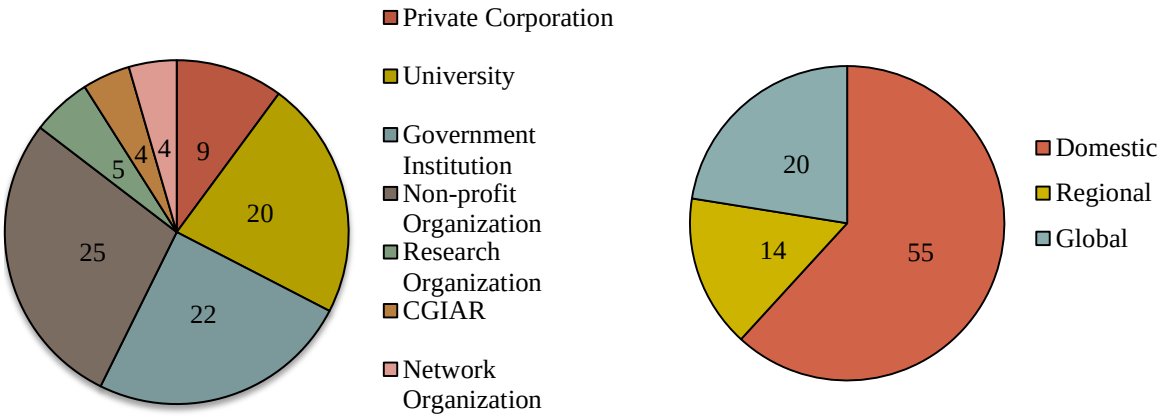

Figure 4.4. Type and scope of CPWF-M partner organizations

4.4.2 CPWF-M Effectiveness in Partnership Areas

One criticism of large international research for development programs is that they work closely within the research communities and do not always expand partnerships with unlikely actors. **Figure 4.5** shows responses to the question "CPWF-M brings together actors who do not normally work together". Sixty-eight percent of respondents selected "agree" or "strongly agree" to this question. Eighteen percent neither agreed nor disagreed, while thirteen percent disagreed with this statement.

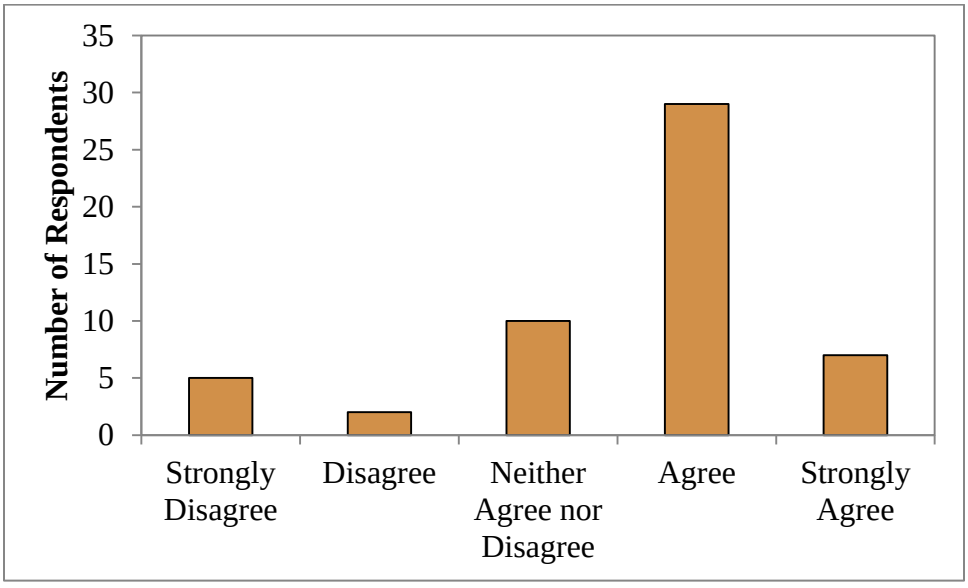

Figure 4.5. Effectiveness of CPWF-M ability to bring together actors who do not normally work together

Although this question points to a clear confidence in CPWF-M partnership skills, a more profound articulation of this outcome was that over half of the respondents indicated CPWF-M partnership and networking capacity as the key strength and outcome of the ten year program in the short answer section of the survey. Additionally, several respondents as well as several interviewees articulated that one success of CPWF-M partnerships was the unique opportunities for non-traditional funding mechanisms. These partners communicated that many large granting organizations, such as AusAID or USAID or even the larger CGIAR Centers, are difficult to obtain grants from because they work on such large scale efforts and rarely have the time or capacity to fund small local research projects. This unique funding mechanism also helped to build the capacity of local and regional researchers. Although some quantifiable measures relating to the success of CPWF-M partnerships were articulated in the online survey, select respondent quotations (**Table 4.5**) summarized the efforts of CPWF-M as meaningful and well respected.

Table 4.5: Partnerships, easy to describe, difficult to quantify

"[CPWF-M] can bring together many different players in the region in regional partnerships".
"[A strength is] bringing scientists to work along with private business without major conflict"
"[CPWF-M] can bring all relevant stakeholders to discuss Mekong issues".

4.4.3 Suggestions and Limitations from Respondent Comments

One important issue raised by respondents was the depth of participation of some associated partners. Several partners articulated that while diversity and representation at meetings clearly showed multi-stakeholder and multi-sector participation, government ministries and most of the private companies had little meaningful participation in CPWF-M programs. This issue relates to the concerns regarding CPWF-M policy outcomes. Additionally, several respondents from the online survey as well as several

interviewees pointed to rising tension between CPWF-M, WLE, and IWMI, which lead to difficult bureaucratic situations, among other things.

4.5 CPWF-M Networking Outcomes

CPWF-M has brought together nontraditional stakeholders within the hydropower sector in the basin. To further analyze their social network, survey respondents were asked direct measurement questions so as to analyze the watershed research and development network throughout the Mekong Basin.

4.5.1 CPWF-M Effectiveness in Networking Areas

The agreement rating of two networking questions evaluated CPWF-M effectiveness in two networking aspects. First, respondents were asked to agree or disagree with the statement that "*CPWF-M is a powerful networking initiative in the Mekong Basin"*. Respondents were also asked to agree or disagree to the statement that *"CPWF-M facilitates discussion about Mekong Basin threats and priorities among your group and other groups within the basin"*. As shown in Figure 4.6, most respondents agreed that CPWF-M facilitates discussion within the Mekong Basin.

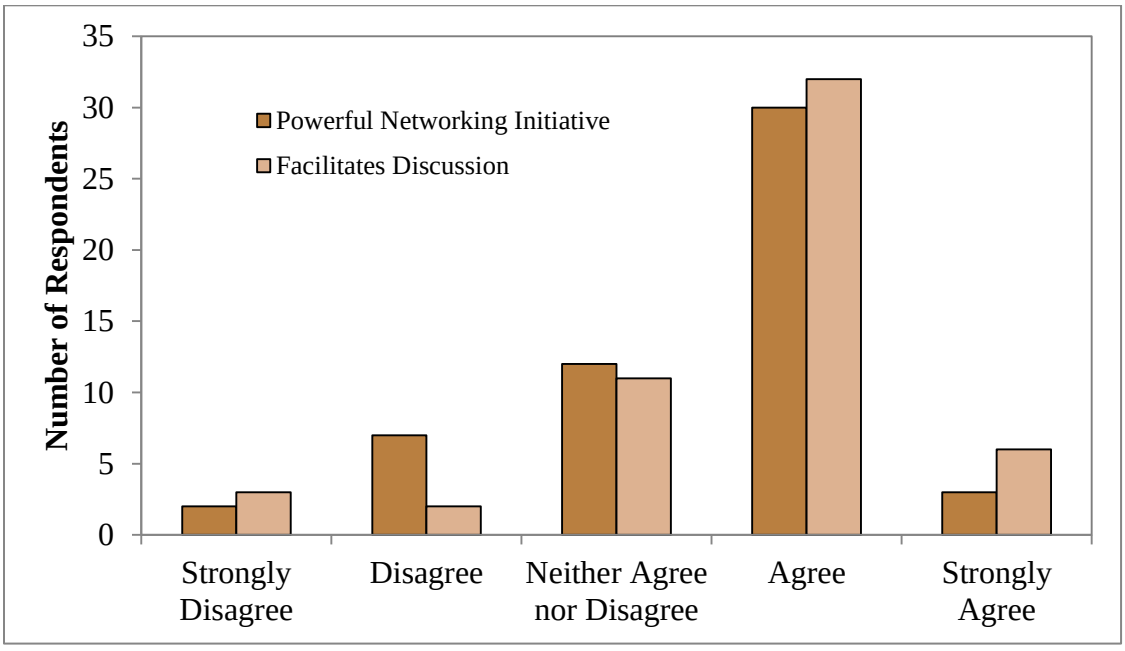

Figure 4.6. Effectiveness of CPWF-M ability of networking initiatives

Of the three Likert scale questions discussed within, the question which asked to what extent the respondent agreed with CPWF-M as a discussion facilitator resulted in the highest average score. In turn, CPWF-M as a powerful networking initiative ranked the lowest when comparing the total average response on a 1-5 scale. This question however still yielded 61% of respondents who agreed or strongly agreed with the statement.

4.5.2 Survey Social Network Analysis

In conjunction with questions relating to rating CPWF-M, respondents of the online survey were asked to identify the partners with whom they worked. The analysis of water management social networks in the Mekong River Basin can allow for the evaluation of power dynamics and improve decision-maker strategies by identifying critical organizational nodes. The study of networks can provide empirical information on the enabling environment within the field of natural resource management (Shrum and Beggs, 1997). One page of the survey however, asked respondents to identify all of the organizations that they work with in the Mekong Basin. The full list of formal and informal partner organizations to CPWF-M was used to create a structured format for survey questions. Because a list of 89 organizations may overwhelm a survey respondent, a subset of that list along with free-response spaces where respondents could add additional organizations was used to generate the sample of organizations.

Figure 4.7 and Figure 4.8 show two visual representations of the first level network created with responses to the online survey. The survey yielded over 340 links between 107 organizations. To protect the anonymity of survey respondents, the names of all organizations have been removed. These network maps serve to illustrate the complexity of the research for development and hydropower environment within the Mekong Basin. The colors represent the different types of organizations previously identified and the size of the circle relates to the organization's scope. As shown through these figures, there is a wide range of both colors and sizes and a multitude of connections. These network maps begin to describe the relational complexity in development organizations and suggest that evaluating development programs through traditional linear input-output means may not be an acceptable measure of success since connections and interactions are difficult, if not impossible to separate.

Network software, including UCINET and R, were used to analyze critical actors throughout the survey responses. There are many different ways to analyze key actors in social networks (Proven et al., 2007; Anheir and Katz, 2004; Rowley et al., 2005; and many others) but for the purpose of this report, only CPWF-M centrality measures will be discussed. Eigenvector centrality, node degree distribution, and betweeness centrality, three topological network measures, were used to analyze the key actors. The measure of in-degree and out-degree centrality indicates simply if one organization is central or peripheral in the network. The closeness centrality can indicate if an organization is in a position to spread information in the network and betweeness centrality can indicate if an organization is a gatekeeper in the network. The results from statistical network analysis indicate that according to these respondents, CPWF-M is among the top 10 critical actors for all centrality measures. This indicates CPWF-M as an important node to the overall network structure.

4.5.3 CPWF-M Phase II Project Network Analysis

The network maps for CPWF-M serve as a reminder of the complexity of research for development environment. To investigate the functions of these networks, a bipartite map of the CPWF-M Phase II projects was also created based on CPWF-M documents. The white circles identify the projects while the colored circles identify the partner organizations. As shown in Figure 4.9, many organizations worked on more than one Phase II project. This indicates that there could have been some connectivity between several different Phase II projects. It also could indicate that in several cases, a small group of organizations were awarded large amounts of funding from CPWF-M.

4.5.4 Suggestions and Limitations from Respondent Comments

While networking initiatives were clearly a strength of CPWF-M, there were a few concerns presented by partner organizations. Some felt as though CPWF-M focused too much on these networking and communication events and therefore lost focus of research outputs and outcomes. This articulates a difference in values between a few partners and CPWF-M staff. Additionally, a few partners questioned the role and functioning of the other networking organizations within the basin. For example, two partners who were

interviewed suggested that if CPWF-M was to serve as a networking organization, perhaps investing money into existing network organizations might have been more useful than creating a completely new program from scratch (CPWF-M) for just ten years. While it is impossible to further investigate this suggestion, it is a point that can be contemplated as organizations develop and flourish in the future.

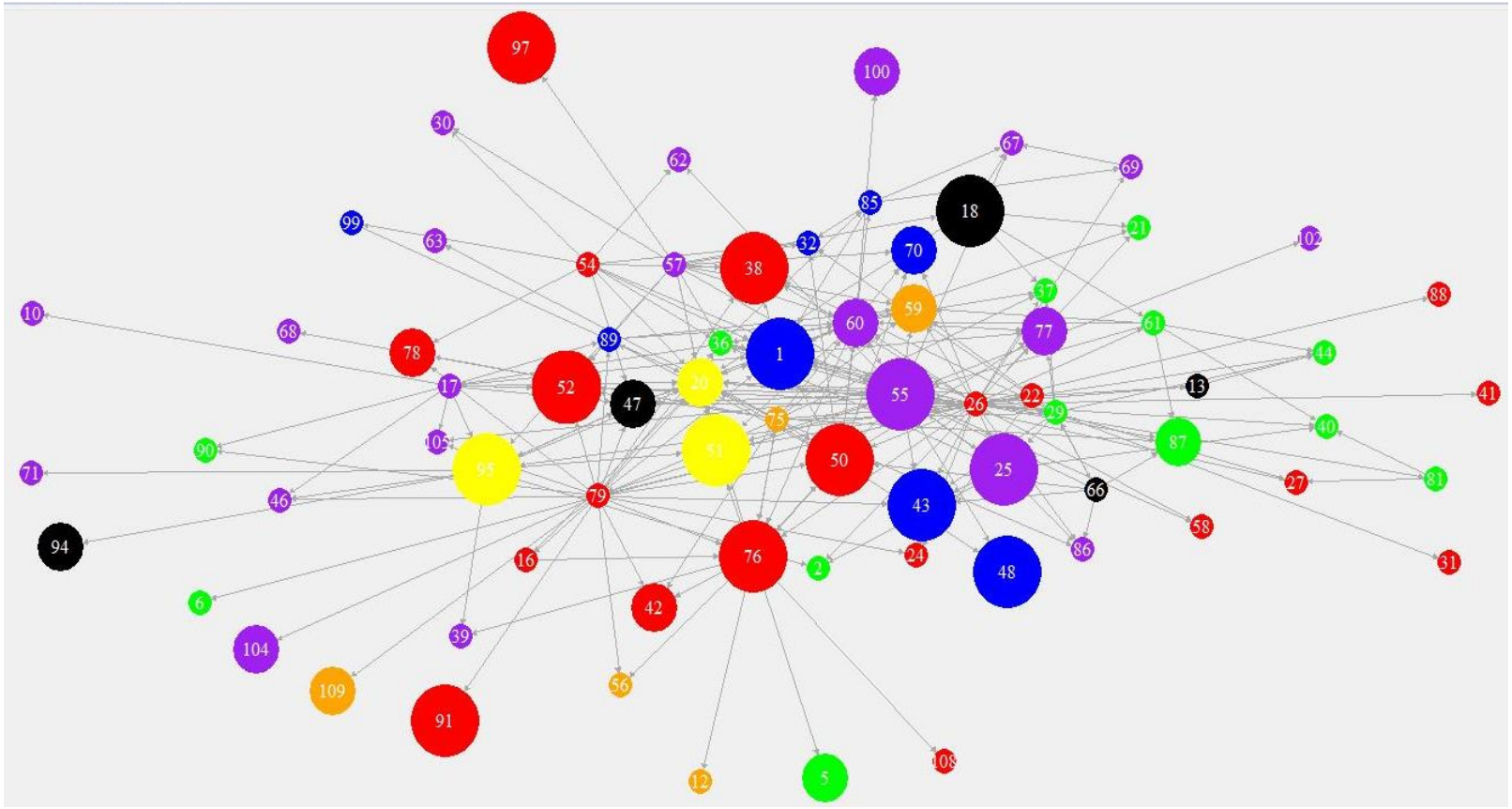

Figure 4.7. Network map of CPWF-M partner organizations

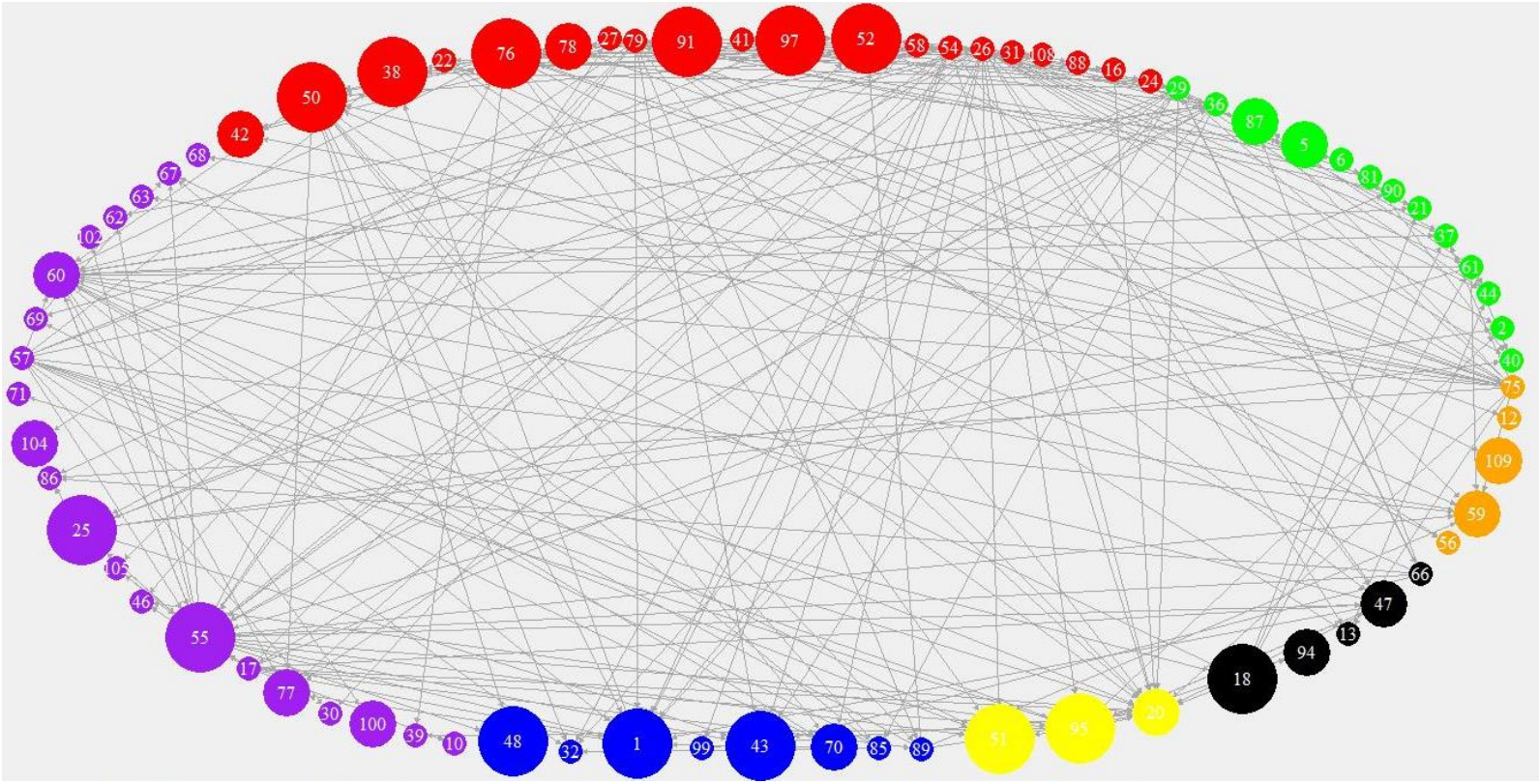

Figure 4.8. Network map of CPWF-M partner organizations arranged by type

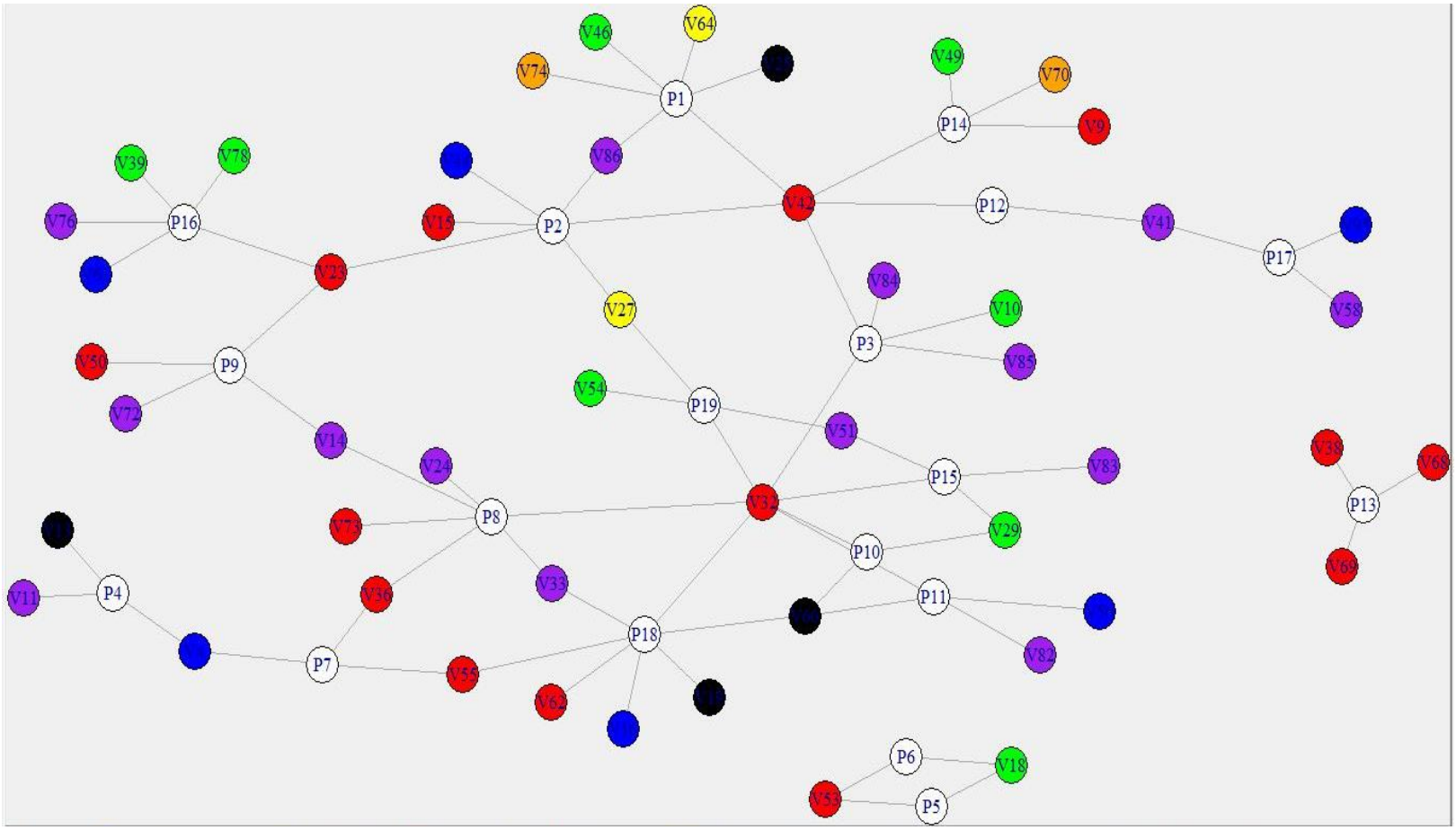

Figure 4.9. Network map of CPWF-M phase II projects

4.6 Future Outlook, Reflections, and Lessons Learned

4.6.1 CPWF-M Future Value

Two questions were asked of survey respondents to gauge overall opinions and perceptions of the CPWF-M program. Respondents were asked if CPWF-M was meeting their needs as a researcher or manager within the basin and if they believe a program similar to CPWF-M would be useful in the future. As shown in Figure 4.10, the majority of respondents believe that their needs are at least partially met by CPWF-M.

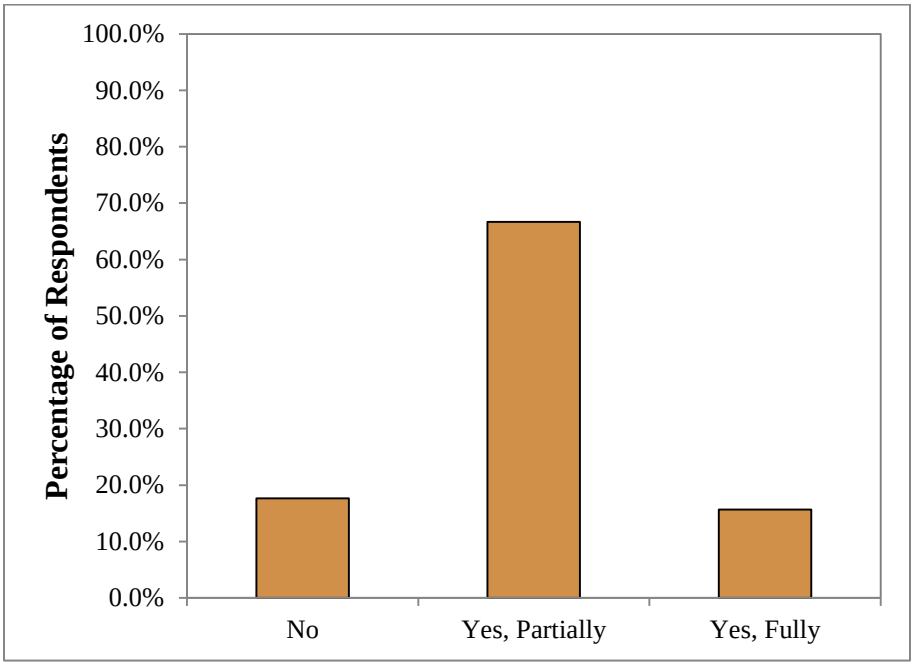

Figure 4.10. Effectiveness of CPWF-M meeting partners needs

Figure 4.11 shows that over 80% of all respondents agree or strongly agree that a program similar to CPWF-M would be important in the future. For those that did not agree, 9% responded neutrally to the statement while only about 5% responded with some type of disagreement. This is the highest rated question of all of those asked throughout the survey. Of all questions, this question may prove to be the most noteworthy in terms of future implications for the Mekong River Basin. Despite respondent's comments and critiques of various aspects of CPWF-M, most respondents believe this program would be an important asset in the Mekong Basin research for development community.

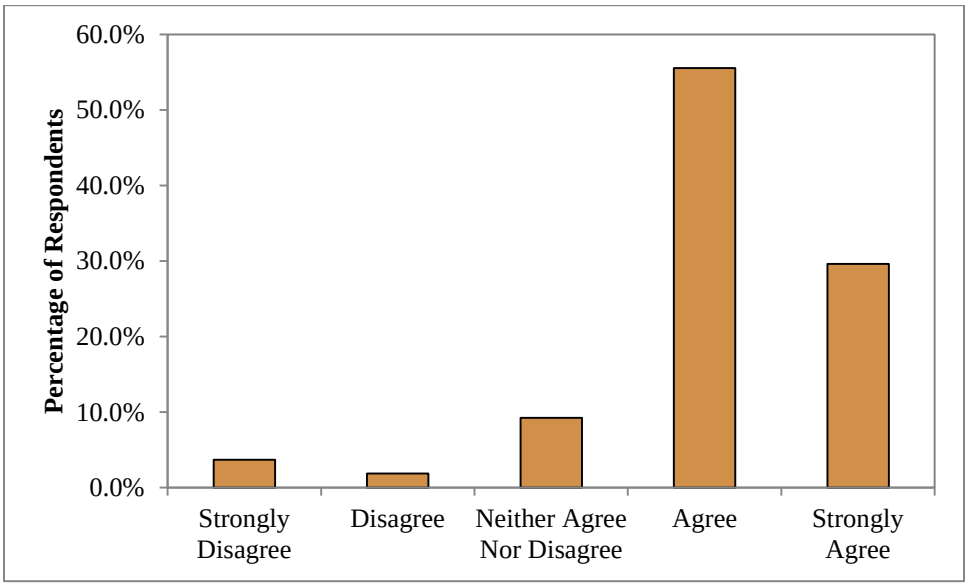

Figure 4.11. Future program value in the Mekong Basin

4.6.2 Common Themes

There have been many successful gains facilitated by CPWF-M in the Mekong Basin throughout the ten year program. Although it is coming to a close across all watersheds, CGIAR should evaluate the overall goals of this program as it translates to continued work with other CGIAR and IWMI initiatives. If the CGIAR is interested in strengthening the networking ability of particular centers, much can be gained from continued evaluation of the process and outcomes of CPWF-M. Two key achievements observed throughout this analysis include:

1. CPWF-M contributed substantially to facilitating unlikely discussions on sustainable hydropower.

Bringing together organizations who do not normally work together is the first step to facilitating truly important development outcomes. Although there are still many research and development challenges throughout the Mekong Basin, the role that CPWF-M played in beginning the conversation on the multi-sector challenges relating to watershed management served an important purpose throughout the ten year program. Getting people and organizations that have fundamentally different outlooks and opinions

on the state and future of hydropower to sit at the same table together, even if many critical management decisions have yet to be altered, is still a major success and should not go without mention.

2. CPWF-M contributed to building capacity to local and regional researchers throughout the Mekong through unique funding mechanisms.

In addition to partnerships and networking, the unique funding mechanisms of CPWF-M filled a niche for many basin researchers that would have otherwise been absent. This strength can be explored when developing future funding initiatives. There is also room to grow and deepen partner relationships. Insuring that partnerships reflect a meaningful exchange of ideas and progress instead of obtaining partnerships that exist in name only will continue to contribute to the success of network and research for development organizations.

This study also indicated that many partners became frustrated with the perceived abrupt ending to the CWPF-M program. While many of the physical research outcomes have yet to be fully utilized by partners, there was consistent belief that the work developed by CPWF-M and by partners of CPWF-M was just beginning to reach impact and had not been given the chance to grow. Due to this, it is difficult to draw conclusions on the scalability and broader applications of CWPF-M research projects. Additionally, many partners articulated the potential value of having information on successful household level projects packaged in a way that could be utilized for larger scale programs.

In general, research for development challenges in the Mekong Basin are among some of the most difficult of all transboundary watersheds worldwide. This presents a unique opportunity for meaningful change and continued progress. Communication of research results and dissemination to not only communities and other academics, but also governments and private corporations is critical for any future groups throughout the basin. It is also important to remember that research results and development work are perceived differently throughout the various countries in the Mekong Region. The outputs from CPWF-M and from many other organizations in the basin are well received

by some countries, and are by others. While working on transboundary watersheds has very high relevance in the international community, it is important to remember that research and development work appeals to countries and localities in different ways and messages should be crafted to reflect those differences.

CHAPTER 5. INTEGRATING SOCIAL NETWORK ANALYSIS WITH ANALYTIC NETWORK PROCESS FOR INTERNATIONAL DEVELOPMENT PROJECT SELECTION

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5.1 Abstract

The social relationships between development agencies, non-governmental organizations, private companies, and other groups working on development projects play important roles in the overall success of projects. However, traditional project selection and prioritization processes ignore the organizational relationships. This paper proposes to integrate social network analysis into multi-criteria decision-making processes to enhance the effectiveness of project selection. A set of topological metrics of social networks are used to quantitatively measure the organizational relationships and integrate them into the analytic network process (ANP) to form a multi-criteria ANP project selection model. Utilizing empirical social network data of a water and food security research for development network in the Mekong River Basin, we investigate the effectiveness of the proposed model is examined. The results suggest that it will offer companies, government agencies, and other donor organizations the opportunity to prioritize strategic network goals simultaneously with research and development priorities, and help companies and research organizations to increase their impact and reach within networks.

5.2 Introduction

Across the globe, there are roughly 850 million people who remain chronically hungry, 780 million people without access to clean drinking water, and 2.5 billion people without access to sanitation facilities (FAO, 2013; UNICEF & WHO, 2013). For decades, international development agencies have loaned, invested, and donated billions of dollars worldwide to combat poverty and work to provide everyone with these basic human rights such as food, water, shelter, and healthcare. The Official Development Assistance of $127 billion dollars in 2012 includes disbursements from the Organization for Economic Co-operation and Development's Development Assistance Committee (DAC) (World Bank, 2014). In addition to government distributions there are billions of dollars more in expenditures from both private philanthropic and non-governmental organizations each year. The Bill and Melinda Gates Foundation alone spent $2.6 million dollars on global grants and programs during the 2012 fiscal year (Bill and Melinda Gates Foundation, 2013). These massive resources are allocated through international aid, loans, investments, or a combination of these and other efforts. In the current economic climate, both public and private organizations are pushing for strong accountability of expenditures and proper utilization of funding. Often the associated projects fail to meet intended objectives, for any number of reasons including but not limited to a lack of local perspective from project implementers, trying to accomplish too much in a short timeframe, or not having social capital or support for continued project success after implementation. For example, a comprehensive external review of 133 completed World Bank projects showed that 50% of projects failed to meet the original objectives of the project (Marwanga et al. , 2006). As a sector example, the percentage of water and wastewater treatment projects that fail to be sustained for long term use ranges from 10-75%, with commonly found estimates that state half of all water projects fail within five years (Elmendorf & Isely, 1981; Harvey & Reed, 2007; The World Bank, 2004; Dale Whittington et al., 2009).

Due to the ineffective development interventions, there is an increasing need to select and prioritize a project for funding that has the highest potential for long-term

success. These multifaceted factors lead to choosing projects to allocate funds using a variety of complex multi-criteria decision-making techniques. There are many multi-criteria decision techniques for modeling decisions including optimizing and prioritizing project selection in various settings. Some popular techniques include information system approaches such as the TOPSIS method (Boran et al., 2009), the PROMETHEE method (Brans et al., 1986), the goal programming model (Santhanam & Kyparisis, 1995), and a number of others as described by Figueria et al. (2005). One decision-making technique that has previously been utilized for project selection of research and development programs is the Analytic Hierarchy Process/Analytic Network Process (AHP/ANP) (e.g. Amiri, 2010; Aragonés-Beltrán et al., 2010; Archer & Ghasemzadeh, 1999; Habib et al., 2009). While other techniques have notable benefits, the AHP has been highly regarded because it can relate any element of a complex problem to a quantitative measurement even if the problem has difficulty to quantify components.

Classical project selection models focus more on the individual attributes of the candidate projects and therefore the decision-making criteria do not account for the interdependencies among alternative projects. Some project selection studies (Santhanam & Kyparisis, 1995) realized that interdependencies exist among alternative projects and proposed nonlinear programming formulations to address the resource, benefit and technical interdependencies among candidate projects. However, one type of project interdependency, i.e., the inter-organizational communications and social relationships, has never been considered in existing multi-criteria project selection models. Trust and communication between project coordinator and task manager are critical factors in successful development projects (Diallo & Thuillier, 2005). Another study of successful development project criteria in Southeast Asia suggested that using participatory planning and stakeholder participation will lead to more successful projects (Khang & Moe, 2008). The relationships between an organization and the broader network of entities working in the international development community have strong implications for the overall functioning of that organization. Global civil society, which refers to the large array of non-governmental organizations worldwide, has often been referred to as a highly networked and relational group (H. Anheier & Katz, 2004; Castells, 2000). The social

relationships between development agencies, non-governmental organizations, private companies, and other groups working on development projects play an important role in the overall success of projects and the working community as a whole.

The inter-organizational communications and the social relationships between organizations can be considered as a new set of evaluation criteria in the project selection model. These communications and the social relationships criteria can be measured by applying metrics developed in Social Network Analysis (SNA). SNA investigates the connections and relationships among social entities and draws patterns and implications from these relationships (Wasserman, 1994). Like all network analyses, it is based on the assumption that there is importance in the relationship among the interacting units. Investigating the network structure and properties is the most common method of analysis used in organizational network research (Provan et al., 2007). The metrics based on the network structural data can investigate the causes of structures or the consequences (S. P. Borgatti & Foster, 2003). Network analysis is well-suited for investigating the relationships of organization communities such as research for development groups that rely on research outputs being utilized by other groups as a sign of effective programs (Aberman et al., 2012; Shrum & Beggs, 1997).

Inter-organizational communications and the social relationships could be integrated into a variety of multi-criteria project selection methods. However, the ANP model was chosen because it allows for practical integration of social network data within its easy-to-comprehend formulation. This indicates ANP is an appropriate choice for organizations in the development community interested in leveraging interdependencies with project selection procedures. Due to these factors, integrating social network analysis with the ANP could yield more successful outcomes and development interventions throughout the world.

This paper is motivated by real-world practical needs arising from the perspective of a donor organization in the water and food security research for development network in the Mekong River Basin. In the broader research for development community context, these needs can be characterized as follows. First, there is the need to select and fund project proposals that will succeed in meeting research or development goals. Second, a

donor organization also seeks to increase its social capital by strengthening its standing in the network of organizations within the given field by connecting with the key players in the social network. While bridging these two important gaps in the current literature, this paper illustrates the application of a multi-criteria ANP model for international development project selection that integrates social network relationships into project selection, which can be applied to numerous disciplines. In addition to project selection outcomes, leveraging traditional applications of ANP in conjunction with traditional social network analyses can also serve to further and strengthen social network analyses. Empirical data from a social network of R4D organizations in the Mekong River Basin is used to analyze the proposed model. This model can be a systematic tool resource for development donors and grant recipients in the Mekong Basin and the larger research for development community worldwide. Building social network criteria into an AHP/ANP model allows for the development of this model that can be applied in many project selection problems in multiple disciplines. However, to the best of our knowledge, none of the existing decision-making model approaches factor the inter-organization relationships in the project selection process.

5.3 Analytical Formulation

Assume there are M (development) projects that are under consideration by a donor. The donor has a set of criteria, denoted by $\{e_j | j = 1, \dots, N\}$, for project evaluation. Let each project be associated with a final numerical score τ_i, $i = 1, \dots, M$. The project selection process is to determine the scores τ_i based on the given criteria $\{e_j\}$ through a multi-criteria decision-making model, such that the set of projects can be prioritized according to their scores τ_i and the optimal alternative can be identified.

In this study, ANP is employed as the multi-criteria decision-making model to determine the scores τ_i of candidate projects. In the rest of this section, a brief review of the ANP will be presented first, followed by the social network analysis and the proposed integrated model.

5.3.1 Analytic Network Process

ANP is a comprehensive model that is appropriate for making multi-objective, multi-criterion and multi-actor decisions with and without certainty for any number of alternatives. As the ANP is a generalization of the AHP, a short review of AHP is included in this section. AHP was developed to quantify the importance of a set of criteria in a multi-criteria decision-making problem. Since AHP is based on value rankings, it has been used and applied by companies and organizations in the real world whereas more mathematically complex models may not be easily transferred from advancing research theory into real world practice. Additionally, AHP models have been used effectively to optimize project selection in the research and development settings (Amiri, 2010).

A classical AHP can be constructed as follows. The goal, criteria, and alternatives form at least three levels of a linear hierarchy tree. After determining the overall goal and the criteria and alternatives for a particular decision, the pairwise comparison can be obtained. This pairwise comparison can be based on value choices from individuals involved in the decision-making and are often based on a 1-9 scale of importance (Saaty, 1996). Let a_{ij} denote the comparison of the strength of criterion i to criterion j. Based on a priority vector $w = (w_1, \dots w_n)$ for the overall goal, criteria and alternatives determined by the decision-maker, the pairwise comparison of criterion i to criterion j is computed by $a_{ij} = w_i/w_j$; similarly, $a_{ji} = w_j/w_i$. And thus, $a_{ji} = 1/a_{ij}$. Then, for the set of decision criteria $e = \{e_j \,|j = 1,2, \dots, n\}$, the pairwise comparison of *n* criteria can be summarized in the matrix:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix} \qquad a_{ji} = 1/a_{ij}\,, a_{ij} \neq 0 \tag{1}$$

where every element a_{ij} $(i, j = 1,2, \dots, n)$ is the quotient of weights of the criteria. The priority vector, or relative weights, of the set of criteria are determined by the right eigenvector *w* of matrix A which corresponds to the largest eigenvalue λ_{max}, i.e.,

$Aw = \lambda_{max}\, w$. This is necessary because the matrix is formed based on human value judgments which are intrinsically inconsistent and this method can provide validity of the priorities of a decision (Saaty, 2003). A pairwise comparison and subsequent eigenvalue calculation is completed by the decision-maker for each criteria and set of subcriteria. The final score of $\tau_i, i = 1, \dots, M$ for each alternative is obtained by summing each alternative's relative weight with respect to each criteria multiplied by the criteria's priority with respect to the goal.

The ANP, which is a derivative of AHP based on the benefits, opportunities, costs, and risk values, has also been used in many applications multi-criteria decision-making (Saaty, 1996, 2004) including project selection (Habib et al., 2009). Both ANP and AHP utilize pairwise comparisons to determine weights of the criteria used in order to make a decision. These weights can then be used to determine which alternative or option, within a selection of potential decision outcomes, is the most optimal based on criteria weights. Alternatively, the weights derived from the AHP process can also be applied to other multi-criteria decision models (Amiri, 2010). Unlike AHP, the ANP has the ability to allow the decision criteria to interact and for the criteria to be affected by the alternatives. Thereby, while ANP is more involved mathematically, it provides a broader, more realistic approach to multi-criteria decision-making.

Both the AHP and ANP models are based on a comparative judgment of the alternatives and criteria. Since ANP dismisses the hierarchical structure associated with AHP it allows criteria to interact with each other. After creating the local priority matrix for the criteria, which consists of deriving matrix A as previously described for each criteria, a supermatrix is formed:

$$B = \begin{array}{c} \\ C_1 \\ \\ C_2 \\ \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} e_{11} & e_{21} & \cdots & e_{nn} \\ e_{11} & & & \\ & & & \\ & & & \\ & & & \end{bmatrix} \\ \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{22} & \cdots & A_{2n} \\ A_{31} & A_{32} & \cdots & A_{3n} \\ \vdots & \vdots & \ddots & \vdots \\ A_{n1} & A_{n2} & \cdots & A_{nn} \end{bmatrix} \\ \begin{bmatrix} \vdots & \vdots \\ e_{nn} & \end{bmatrix} \end{array} \tag{2}$$

where C_n is the nth cluster with criteria or element e_{ij}, and each A_{ij} is the local priority matrix as described in the AHP formulation evaluating the relative priority between cluster i and cluster j . Although this supermatrix allows for influence of every element on every other element, if two clusters have no influence on one-another, then A_{ij}=0. While criteria can be grouped into clusters, a cluster could also contain only one criterion. After determining the local weights using the eigenvector value, the global weights are calculated by raising the supermatrix to limiting powers:

$$\lim_{k\to\infty} B^k \tag{3}$$

Raising the supermatrix to compute the limiting priorities allows for the determination of whether the supermatirx is reducible or not. This permits for normalization and allows the control criteria to not be dependent on the alternatives. Unlike AHP, the ANP supermatrix allows for interdependence between all of the elements (criteria and alternatives).

In classical AHP applications for project selection, all criteria considered in the model are related to the attributes of individual project or grantee. The inter-organizational communications and the social relationships between organizations can be considered as an additional cluster of evaluation criteria C_n in the model. In the next section, a set of metrics developed in social network analysis is introduced to evaluate the inter-organizational communications and the social relationships that are used in the integrated model.

5.3.2 Social Network Analysis

In a social network, entities (e.g. people, organizations, countries, etc.) are connected in various ways with various levels of interaction. The entity is referred to as a node while the connections between entities are known as links. For this empirical example, the nodes include organizations in the research for development network and the links represent three different types of connections. Two common topological metrics in a social network are degree centrality (denoted by C_d) and betweenness centrality

(denoted by C_b). Given a network $G:=\ (S, L)$ with $|S|$ nodes and $|L|$ links, Equations (4) and (5) represent these two metrics for any node $s \in S$:

$$C_d(s) = deg(s) = \sum_j X_{sj} \quad (4)$$

$$C_b(s) = \sum_{i \neq s \neq j \in S} \frac{\sigma_{ij}(s)}{\sigma_{ij}} \quad (5)$$

where X_{ij} and σ_{ij} represent the number of links and the shortest distance of links connecting a pair of nodes (i, j), respectively, and $\sigma_{ij}(s)$ represents the number of those shortest paths that pass through node *s*.

Centrality measures can provide useful information about the functioning of the social network. For example, if an organization (node) has a low betweenness value and a high degree value, this organization's connections are repetitive and communication can potentially bypass them with no adverse consequences. Conversely, if an organization or node has a low degree but high betweenness value, that organization's ties, while few, are critical to the overall functioning of the network.

Network analyses can be used to identify the organizations or actors in a network that serve as integral links to that network, also known as a key player(s). The key player problem consists of two subproblems: (i) *node disruption*: determining the node or set of nodes that, if removed, would maximally disrupt communication among the remaining actors, and (ii) *node reach*: determining the node or set of nodes that is maximally connected to all the other nodes (Borgatti, 2003). Given this problem, the network analysis results could be used by an organization to increase its reach within a network by becoming associated with the key player(s).

Identifying the key player in a social network is not computationally straightforward (Borgatti, 2003). While the key player problem in social network analysis can refer to both node disruption in the network and node reach in the network, for the purpose of this study we are only concerned in organizational reach and therefore the latter of the two key player problems. Utilizing this measure has multiple applications. For example, an organization could use this in order to identify a small group of other organizations to use as seeds for diffusing new work practices effectively within the network. Distance weighted reach (*R*), the value of reach capital that one node holds, can

be defined as the sum of the reciprocals of distances from the key player *S* to all nodes (Borgatti, 2003). This distance from a set to a node outside, for our purposes, is the minimum distance from any member of the set to the outside node.

$$R = \frac{\sum_j \frac{1}{d_{Sj}}}{n} \tag{6}$$

In equation (6), the distance from a node *S* to node *j* is represented by d_{Sj}. The summation includes all nodes, and the distance from the node or set of nodes evaluated to a node within the set is defined to be 1. If there is no path connecting node *S* and node *j*, then the distance d_{Sj} is infinite, and the reciprocal of an infinite distance is 0. In this setting, *R* is the proportion of all nodes reached by the set, where nodes are weighted by their distance from the set and only nodes at distance 1 are given full weight. *R* gives us the quantitative value of reach used to determine the "key player" according to this metric.

The centrality measures (C_d and C_b) as well as the distance weighted reach (*R*) are important attributes of candidate projects which help companies and research organizations in evaluating the candidate projects, such that the key players in the social network are identified and the long-term success of the development project can be enhanced. The next sub-section illustrates the multi-criteria ANP project selection model that integrates the project selection criteria from SNA.

5.3.3 The Multicriteria ANP Project Selection Model

This study provides two important advances to the literature on project selection with ANP models. First, unlike any previous work, this paper utilizes the ANP model within a research for development case study. Second, this paper serves as the first example of integrating SNA results to an ANP model through creating nontraditional criteria. In order to allow for SNA results to aid development work we propose three basic stages: (1) identify the criteria to be used in the model, (2) SNA computations, and (3) ANP computations, evaluation of the alternatives, and determination of final rank (Figure 5.1).

In the first stage of Figure 5.1, the decision-making team (donor organization) determines the criteria for which the alternatives (project proposals) will be evaluated. In a traditional ANP model, the decision-making team would proceed directly to ANP calculations (stage 3) after determining the criteria and decision hierarchy. In this model, stage 2 represents the application of SNA computations which is not included in previous ANP models. According to the literature, international development program success is tied to social relational aspects including communication, trust, interorganizational collaboration, and stakeholder participation (Anheier & Katz, 2004; Castells, 2000; Diallo & Thuillier, 2005; Khang & Moe, 2008; and others). This articulates the need for stage 2 which strengthens the traditional project selection techniques utilized in stage 1 and stage 3. Finally, stage 3 represents the convergence of SNA results with ANP calculations which allows for the determination of the final rank.

In this empirical study, the ANP model represented by the supermatrix B, i.e., equation (2) is modified to include both traditional ANP criteria (*A*) and SNA criteria (*D*):

$$B = \begin{bmatrix} A & 0 \\ 0 & D \end{bmatrix} \tag{7}$$

where the matrix *D* includes all the social relationship attributes presented in the previous section. Since both A and D represent criteria, they are still compared utilizing pair-wise decisions. In order to articulate the differences between these criteria and stages, four decision hierarchy trees, described in section 2.4, were used.

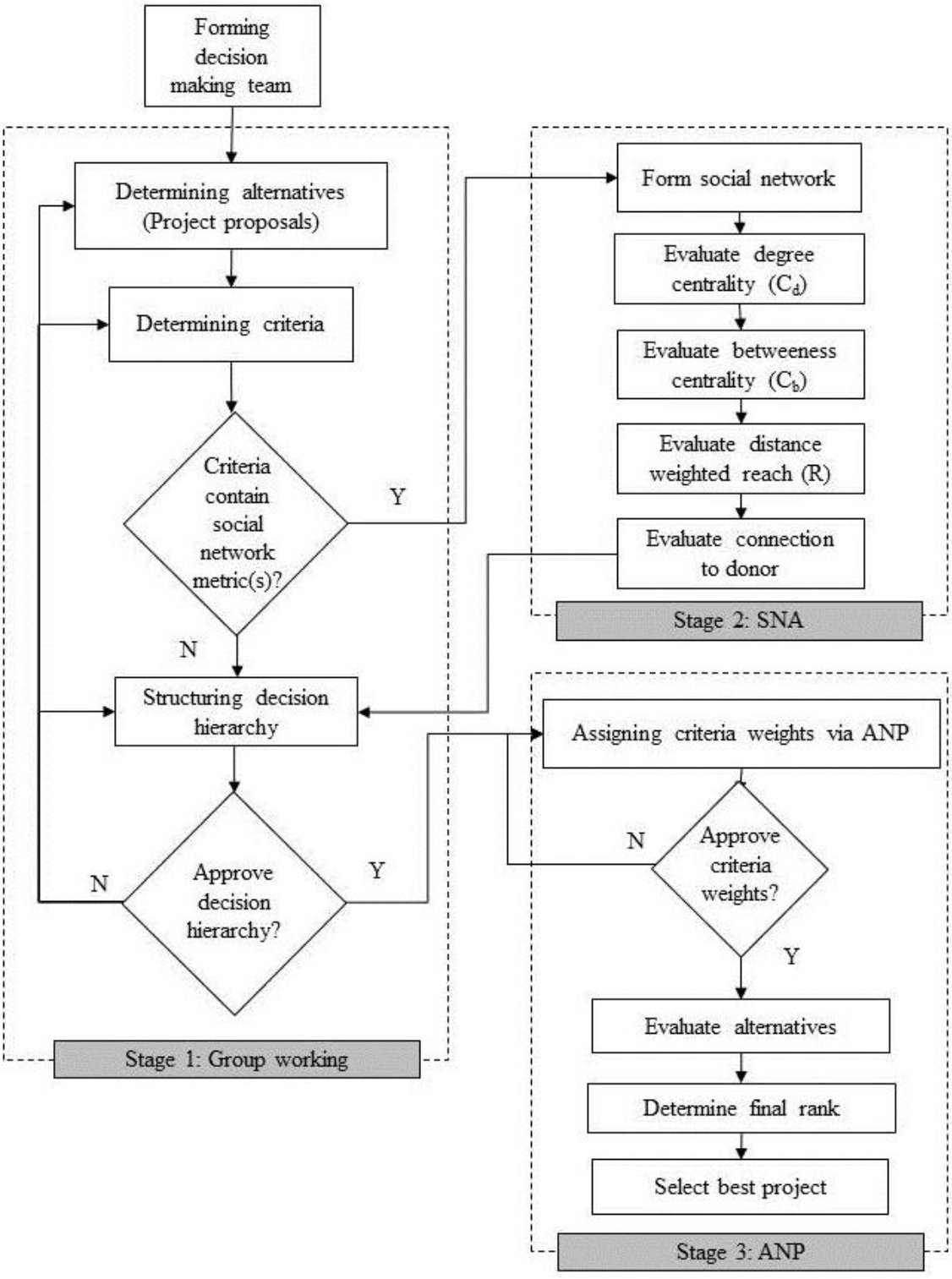

Figure 5.1. Schematic diagram of the proposed model for project selection

5.3.4 Identification and Hierarchy of Criteria in Proposed Model

Criteria to be considered in the selection of projects are determined by previous literature for project selection as well as new SNA criteria summarized into Table 5.1. Eleven criteria and ten alternatives were used in the evaluation process calculated by using the ANP method.

Table 5.1. Criteria and alternatives for project selection.

Label	Criterion	Criterion Type	Definition
C1*	Budget	Cost	Reasonableness of cost estimate
C2*	Overhead	Cost	Reasonableness of terms in contract
C3*	Technical quality	Benefit	Adequacy, level of detail
C4*	Organization experience	Risk	Was the organization proven/evaluated prior to the project proposed?
C5*	Author track record	Risk	Was the author proven/evaluated prior to the project proposed?
C6	Betweeness centrality (C_b)	Opportunity	What is the organization's ability to transfer items through shortest path in the network?
C7	Degree centrality (C_d)	Opportunity	How many other organizations does this organization connect with?
C8	Connection to donor	Opportunity	Is the organization connected to the donor (binary response)?
C9	Distance weighted reach (R)	Opportunity	What is the organization's reach within the network?
C10	Organization Size	Benefit	How large is this organization?
C11	Organization Type	Benefit	What type of organization is it?
**denotes criteria from other project selection studies*			
Alternatives	Description		
A1	Organization m_1 project proposal		
⋮	⋮		
A*n*	Organization m_n project proposal		

Criteria C1-C5 are generic project selection criteria selected to represent traditional project criteria used in previous literature (Amiri, 2010; Wu & Lee, 2007). Criteria C6, C7, C8, C9 are social network criteria calculated based on SNA related to the social network structure or link attributes. Criteria C10 and C11 are related to the organization properties or node attributes of the social network. The alternatives are different organizations from an actual international development social network. These organizations represent project proposals submitted to a donor organization decision making team for international development funding. To determine the benefit of introducing additional SNA criteria, four different hierarchy trees were evaluated (Figure 5.2). In addition, all 11 criteria are categorized into benefit, opportunity, cost, and risk categories. This traditional benefit, cost, opportunity and risk model (BCOR) allows for the development of two different hierarchy trees utilizing all 11 criteria (Figure 5.2B and Figure 5.2C). Figure 5.2 represents multiple scenarios created in stage one, the group working stage, of the proposed model.

Four decision hierarchy trees are constructed in order to model likely scenarios for the priorities of a hypothetical donor organization. In the first case, the donor organization determines that only social network criteria for each alternative organization should be utilized in evaluating the project proposals (Figure 5.2A). This articulates a case where a donor organization project selection team believes that the network relationships of the recipient organization are the only important factors in the overall success of the project. In the second (Figure 5.2B) and third cases (Figure 5.2C) all eleven criteria were used. The shaded boxes in the second case (Figure 5.2B) were weighted at a ratio of α to the unshaded boxes β and $\alpha + \beta = 1$. This is a commonly used weight where a donor organization project selection team ranked the benefits and opportunities (shaded criteria boxes) as more important than the costs and risks (white criteria boxes). Case three (Figure 5.2B) utilizes all criteria with equal weight. The cases 2B and 2C articulate two typical implementation strategies for the proposed model. In the final case, the hierarchy tree included traditional project selection criteria only (Figure 5.2D). This represents the current status of AHP/ANP modeling for project selection which does not integrate any social network analysis criteria. To evaluate the benefit of

introducing additional SNA criteria to ANP model, the proposed model is evaluated using data collected from a Mekong Basin International Development Network in the next section.

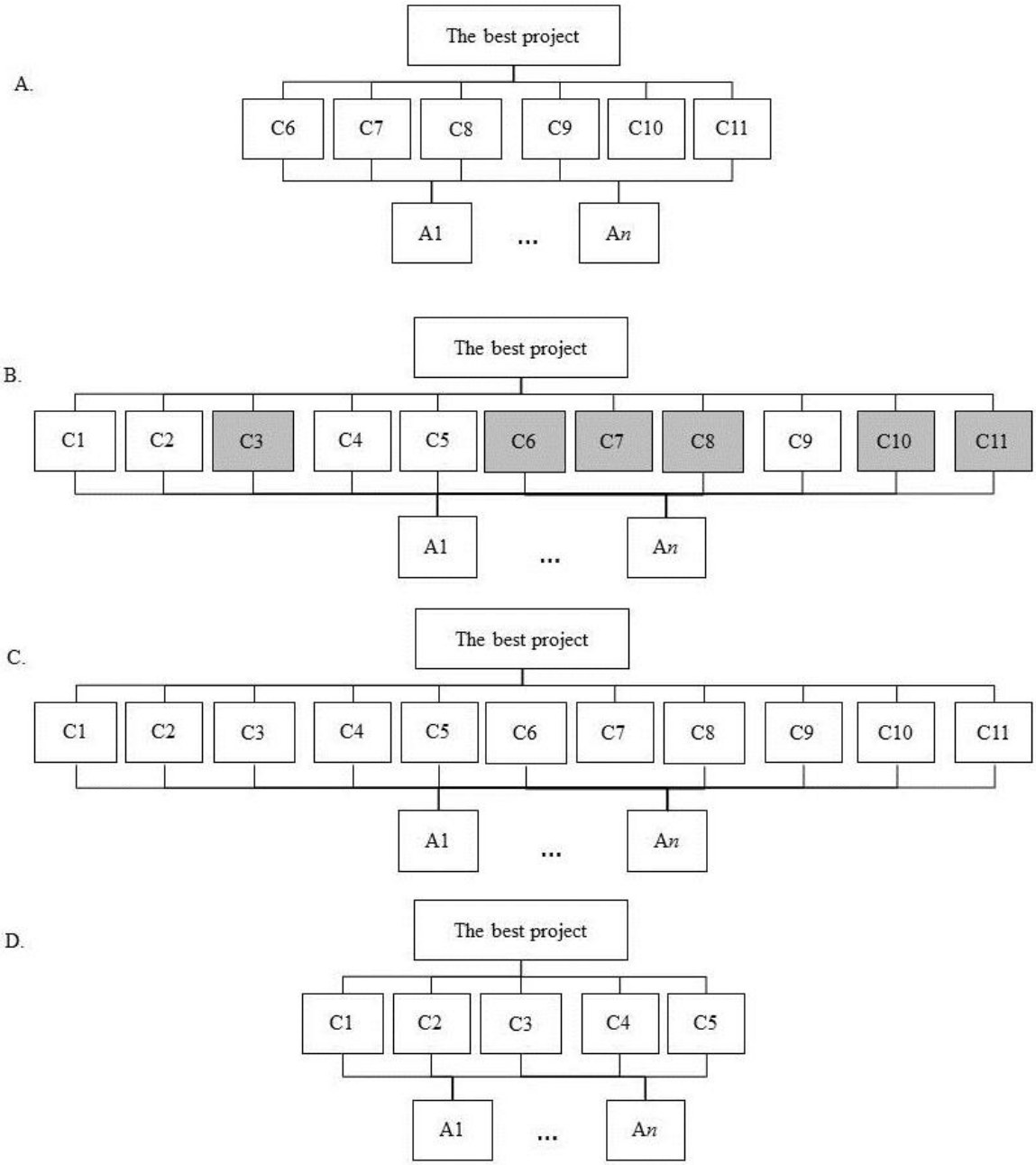

Figure 5.2. The four decision hierarchy trees for project selection.

5.4 Empirical Study and Results

5.4.1 Mekong Basin International Development Social Network

To complete stage 2 of the proposed model, a Mekong Basin International Development Social Network was created. The Mekong River, located in Southeast Asia, is the 10th largest river in the world with a length of 4,909 km (Liu et al., 2007). This transboundary river spans six different countries with headwaters that originate in China's Yunnan province, then flow south into Burma (Myanmar), Lao PDR, Thailand, Cambodia and ultimately outflow from Viet Nam into the South China Sea. The Lower Mekong Basin, comprised of the basin sections within Burma, Thailand, Laos, Cambodia, and Viet Nam, is the most populous and well-studied region within the Mekong River Basin and is home to over 60 million people (Mekong River Commission, 2010). This region is in a transitional period of development as several countries within the basin are pursuing large scale hydropower dam projects. These infrastructure projects will change the natural water flows of the Mekong and could potentially present challenges to water and food security for Mekong Basin citizens. Due to the environmental complexity, research for development activities has been highly regarded by many large international development organizations.

The network model of the organizations in the Mekong River Basin working in research for development related to water and food security was created using a survey. This survey was sent to 101 known organizations whose contact information was provided by a large international research organization. A list of these organizations was used to create a structured format for survey questions. Because a list of over 100 organizations may overwhelm a survey respondent, a subset of that list was used for the survey. 62 organizations that appeared to be most involved with the Mekong River Basin according to their webpages, along with 8 spots where fill-in-the-blank organizations could be written, for a total of 70 selection choices, were used in the online survey sent to organizations involved in research for development activities in the region. The 8 open-ended spots were stratified by sector: government ministries (Viet Nam, Thailand, Lao PDR, Cambodia), non-profit/non-governmental organizations, private companies, universities, and other government organizations.

The survey respondents were asked to explain the level/strength of linkage between their organization and the partner organization(s): (i) *formal*: other organizations that you formally report to, collaborate with, or work with on watershed management in the Mekong; (ii) *informal*: other organizations that you have an informal professional relationship with (i.e. which organization has professionals that you would call if you had a Mekong Basin management question); and, (iii) *familiar*: other organizations that you are familiar with but have had no formal or informal interactions with. The three options enable the building of a network with different linkage levels between nodes.
An overall survey response rate of 59% was obtained. As shown through Figure **5**.**3**, the network produced included 109 unique organizations and 901 different organizational links of varying levels.

Within Figure **5**.**3**, the nodes are shaded according to the organization type (e.g., private company, university, government agency, etc.), and the size of the node is associated with the size or scope of the organization (e.g. global, regional, or local). Additionally, the strength of linkage is associated with the darkness of the line. The labels of each organization have been removed in order to provide anonymity to survey respondents. To complete the project selection model, ten alternatives were selected from this social network (Table 5.2). These alternatives represent real organizations within the Mekong River Basin research for development social network. These organizations were chosen to represent a wide array of organization type, scope, and location in the network that are likely candidates for submitting a project proposal for development funding.

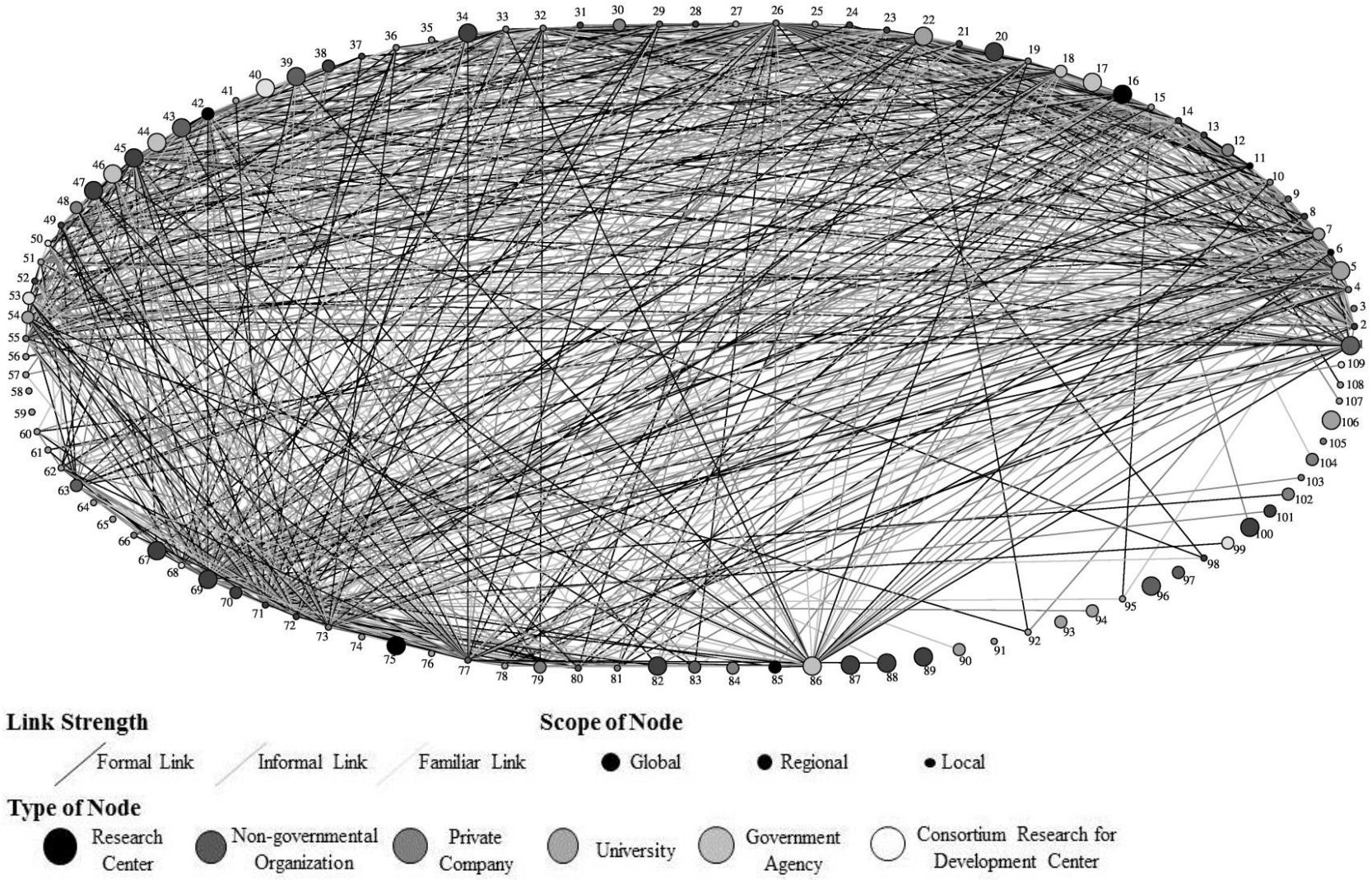

Figure 5.3. **Social Network of Organizations working on Research for Development in the Mekong**

Table 5.2. Alternatives for Mekong Project Selection

Alternatives	Organization Number	Alternatives	Organization Number
A1	Organization 26	A6	Organization 68
A2	Organization 42	A7	Organization 15
A3	Organization 69	A8	Organization 71
A4	Organization 22	A9	Organization 14
A5	Organization 5	A10	Organization 45

Utilizing the key player approach, the 15 organizations with the strongest reach (R) are listed in Table 5.3. The reach and degree rankings varied slightly from one another. This implies that these centrality measures are correlated with one another. However, there is variation in the rankings for degree centrality and betweenness centrality. For example, organization number 2 has a degree rank of 19, which is not very high, but a betweenness ranking of 5. This implies that the connections of organization number 2 hold are more unique and more important to the overall functioning of the network than an organization that has a high degree and betweenness ranking.

Table 5.3. Centrality Metric Rankings for Mekong Social Network

Organization ID	Reach (R) Rank	Degree (C_d) Rank	Betweenness (C_b) Rank
26	1	3	12
69	2	2	2
5	3	1	1
14	4	5	3
42	5	4	10
22	6	6	6
71	7	8	21
15	8	10	14
68	9	14	27
45	10	7	4
23	11	9	25
6	12	13	16
77	13	11	7
73	14	18	20
2	15	19	5

A donor organization, such as the World Bank, US Agency for International Development, or the Bill and Melinda Gates Foundation may utilize this information in order to garner further connections within the network of organizations. Furthermore, as shown next through the project ranking analysis, the proposed multi-criteria ANP project selection model combines these SNA results with ANP in order to evaluate the differences between traditional ANP applications (stage 1 and stage 3) and the addition of stage 2 in the proposed model.

5.4.2 ANP Results

To complete stage 3 of the proposed model, the SuperDecisions Software (Creative Decisions Foundation, 2014) was utilized for the criteria hierarchy and the pairwise comparison of criteria. Traditionally, the pairwise comparison of criteria can be derived from a survey of the decision-makers values but for the purpose of this empirical example, random pairwise comparisons are made for the four hierarchy cases previously articulated (Table 5.4).

Table 5.4. Application of combined ANP with SNA criteria

Case Number	Fig.	Theoretical general pairwise comparisons	Project ranking of first 5 alternatives
1	2A	Pairwise comparisons of social network components only, prioritizing C9>C11>C10 >C7>C8>C6	A1>A5> A2>A3>A9
2	2B	Pairwise comparisons with random values chosen for project criteria with benefits weighted at $\alpha = 0.80$ and cost weighted at $\beta = .20$	A5>A2>A3>A4>A9
3	2C	Pairwise comparisons with random values chosen for project criteria with overall benefits and cost with equal weight $\alpha = \beta$	A5>A3>A2>A8>A22
4	2D	Pairwise comparison of project selection criteria only, prioritizing Technical C3>C1>C2>C6>C5	A6>A9>A8>A1>A3

Table 5.4 further illustrates how the alternatives for funding an organization project vary with the different cases illustrated in **Figure 5.2**. When only SNA criteria were analyzed

(case 1), as an organization might do in order to increase its reach within the network, the results indicated the best organization to fund would be organization 26 (A1), then organization 5 (A5), and so on. In case 1, SNA was the only influencing factor in project selection so the projects selected were all from organizations with high SNA criteria scores. If the donor organization was only concerned with increasing their reach within their social network by utilizing project selection, they would choose to fund alternative A1 using case 1. Cases 2 and 3 indicated that when integrating SNA with traditional project selection criteria, the results can vary. As shown in case 2, the top five alternatives still have high SNA scores because most of the benefit and opportunity criteria, which had a higher weight, were related to the SNA criteria. Case 3 indicates the model which most evenly prioritizes the dual goals of selecting the best project while also increasing the donor reach. In a traditional ANP project selection model a donor organization would select a project to fund without considering the social network criteria (case 4). The results show the donor would fund the project proposal from alternative organization 68 (A6), then organization 14 (A9) and so on. Since this top alternative (A6) does not have an important role in the social network for the Mekong Basin, the donor organization would be funding an organization without key social connections that lead to program success. Hence, using a traditional ANP model (case 4) would produce significantly different results than modeling a project selection process with SNA criteria (cases 1-3).

5.5 Discussion and Conclusion

A multi-criteria ANP project selection model was presented for combining social network topological measurements with traditional project selection criteria to maximize the outcome for the donor organization. Combining two nontraditional fields allows for the opportunity to fund and deploy development projects that are more successful than many underway today. Reducing the failure of development work will strengthen the opportunities to bring millions of people out of poverty worldwide. As shown through the empirical study, the proposed model can incorporate social network metrics in order to aid complex decision-making processes such as project selection for donor organizations.

From the evaluation of results, we are able to derive which grantee organization would increase the donor organization connections within the network while optimizing project selection criteria. The study also articulates the influence of various social network topological measures such as reach, degree and betweenness.

The study approach illustrates several unique features that contribute to the depth of knowledge in social network analysis and multi-criteria decision-making with ANP models. First, integrating social network analysis in this way allows for including both link data, traditionally captured in topological social network analysis, as well as node data, about the organizations themselves which is not often captured and is independent of the link connections. Second, articulating social network features as criteria in an ANP model allows for optimizing two traditionally separate goals, project selection and organizational connections, within a real network. Finally, this work provides an approach to integrate two analytical techniques, which increases complexity yet still remains accessible to managers and researchers in organizations worldwide.

In a real world project selection process, decision-makers would provide value judgments that indicate how the pairwise comparisons of criteria should be done in order to achieve the weights of criteria. This project selection model utilized random values for the information about the proposed project (e.g. budget, overhead costs, technical qualities, etc) as well as the pairwise comparisons of criteria. However, in reality, there would be data for the project alternatives being evaluated. Additionally, the social survey construction can only be as complete as the response rate allows. The achieved response rate of 57% is considered acceptable for an online survey since it is representative of the overall sample (Cook et al., 2000; Nulty, 2008). Despite these issues, we show how utilizing a traditional ANP project selection model, without the SNA completed in stage 2, could lead to a decision-making team selecting an organization without the proper social connections that lead to successful development interventions.

CHAPTER 6. CONCLUSIONS

6.1 Major Findings

The focus of this work was on the evaluation of development practice related to water, sanitation, and food security. The water quality of improved water sources in both Kenya and Vietnam was quantified utilizing *E. coli* as an indicator organism. Household factors that were able to describe and predict households with water and sanitation access in the Vietnamese Mekong Delta were then evaluated based on binary logistic regression. In addition to these household investigations, the overall satisfaction and perception of stakeholders in the Mekong Basin were studied and evaluated. Finally, a potential application of the stakeholder investigation by describing the implications that social network data could have on project selection in development practice was presented. The overall findings of this work are as follows:

1. The majority of improved water sources sampled in Kenya and Vietnam contained measurable *E. coli*. In Kenya, roughly 61% of samples tested were identified as containing *E. coli* at concentrations corresponding to high-risk or very high-risk, as defined by the World Health Organization, levels of *E. coli* and only 18% of samples had no viable coliforms. Of the Vietnamese household samples, 67% were identified as containing *E. coli* at concentrations corresponding to high-risk or very high-risk levels, while roughly 18% had no measurable coliforms. These results illustrate known limitations of the definition of "improved water" by the United Nations Millennium Development Goals and indicate that this definition does not insure the delivery of safe and potable water.
2. The household characteristics that influence water and sanitation access in the Vietnamese Mekong Delta are different from one another. For

access to water, statistical analyses suggested that the number of children 5 years of age or less, the distance a household is to the local market, the sex of the person who manages the water at home, as well as the house and farm size influence access to improved drinking water. Conversely, the factors that influenced access to improved sanitation facilities included distance to local government offices, household food insecurity, farm size, and household building materials. Overall these conclusions suggest that for future development interventions to be successful, we must address the challenges of water and sanitation through different means since the influences of these interventions are not necessarily the same.

3. The Challenge Program on Water and Food Mekong successfully established an important role in the Mekong River Basin international development community. Stakeholder perceptions of the Challenge Program on Water and Food Mekong point to program successes in networking and advancing the discussion on sustainable hydropower. Development practitioners throughout the Basin have identified important research gaps including how irrigation plans relate to hydropower operations, best management practices for farming techniques and livelihood development projects that can be shared and applied in other contexts, studying the decision-making processes for water management, and performing socioeconomic impact studies on communities affected by infrastructure development.
4. Social network analyses have the potential to influence project selection for international development. Combining ANP modeling and social network analyses, two nontraditional fields, allows the opportunity to fund and deploy development projects that are more successful than many underway today. Reducing the failure of development work will strengthen the opportunities to bring millions of people out of poverty worldwide.

6.2 Future Development Practice Improvements

Based on the findings and research carried out within, several general suggestions for future development practitioners and researchers come to mind. As the United Nations Millennium Development Goals expire this year, new and stronger worldwide objectives should be actively pursued to continue reducing poverty and providing access to basic human needs worldwide. Suggestions based on this work include:

1. Chapter 2: Strengthening the definition of "improved water" to include measurable quality standards that target the provisioning of safe water above and beyond provisioning only based on water technology types.
2. Chapter 3: Target water and sanitation development interventions based on different household characteristics. For the Mekong Delta, these characteristics include continuing the standing practice of targeting women water managers for access to improved drinking water. With regards to sanitation access, targeting food insecure households remains a priority.
3. Chapter 4: Strengthen research on current and future hydropower development in the Mekong River Basin so that practitioners working in the region have access to critical data about environmental and social impacts.
4. Chapter 5: Leverage social network information in future development project selection.

In addition to these general conclusions, continued research on monitoring and evaluating previously implemented development programs remains an important facet of this international work. Only by determining the factors of success or failure will programs and organizations evolve to more successfully impact communities in which they work.

6.3 Integration, limitations, and critical future research needs

This work has provided a better understanding of various facets of water and food security in several communities worldwide. Still, there are many research challenges associated with evaluating and implementing future international development. From this work, many specific avenues for research including; water contamination source

detection (Chapter 2), evaluating applicability of Vietnam findings to other parts of the world (Chapter 3), increased research on hydropower in the Mekong (Chapter 4), and model validation for project selection tools (Chapter 5) were identified. Beyond discrete research endeavors however, this body of work points to the disconnected nature of current research for development practice.

Connected avenues of research from this work would allow for the integration of scale and discipline within these studies. Take social network research for example. Different disciplines have noted the importance of social networks in international development. Social network theorists have identified non-governmental organizations as highly relational and cohesive and critical to the development research agenda (Anheier & Katz, 2004; Katz & Anheier, 2006; Lewis & Opoku-mensah, 2006). Likewise, development theory researchers have long since understood the value of community driven responses and the relationships between project implementer and project recipient (Diallo & Thuillier, 2005; Khang & Moe, 2008; Whittington et al., 1998). Yet there is very limited research available which integrates the strong computational principles of social network theory with the hands-on survey work done by development practitioners. In the case of this work, future research endeavors which integrated social network data collection into the resource access assessment would been apt to provide additional insight and stronger conclusions regarding the social influences on water, sanitation, and food security in Vietnam. One reason for why these overlapping fields have yet to capitalize on the potential of integration is because each field functions within the context of traditional literature. For example, social network theorist often rely on complete network information where every actor is accounted for and if that is not the case, these networks are often applied through different techniques including ego network analysis (Wasserman, 1994). Unfortunately, in a development setting, it is virtually impossible to count on a 100% response rate for surveys. In order for interdisciplinary pursues of this nature to be successful, there must be some new boundary's developed for the literature that allow for compromise while still retaining research integrity.

Other fields of study outside international development have identified the critical need for integration of independent research areas including the disaster risk, climate

change, and resource management communities (Schipper & Pelling, 2006). It is time for the research community studying international development to make similar acknowledgements and work towards a stronger interdisciplinary future. Without new ways to understand previously implemented programs, the international development research literature will remain dominated by small site case studies which, while important, are unable to address larger worldwide challenges. There are still billions of people worldwide who do not have clean water to drink or enough food to eat. In a globalized economy, we have the power to combat this poverty through continued dedication to human wellbeing worldwide. Research has the potential to contribute informed, important, and critical findings that can strengthen the development agenda moving into the next decade and beyond.

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APPENDICES

Appendix A Water Quality Results

Figure A: Arsenic concentrations by village

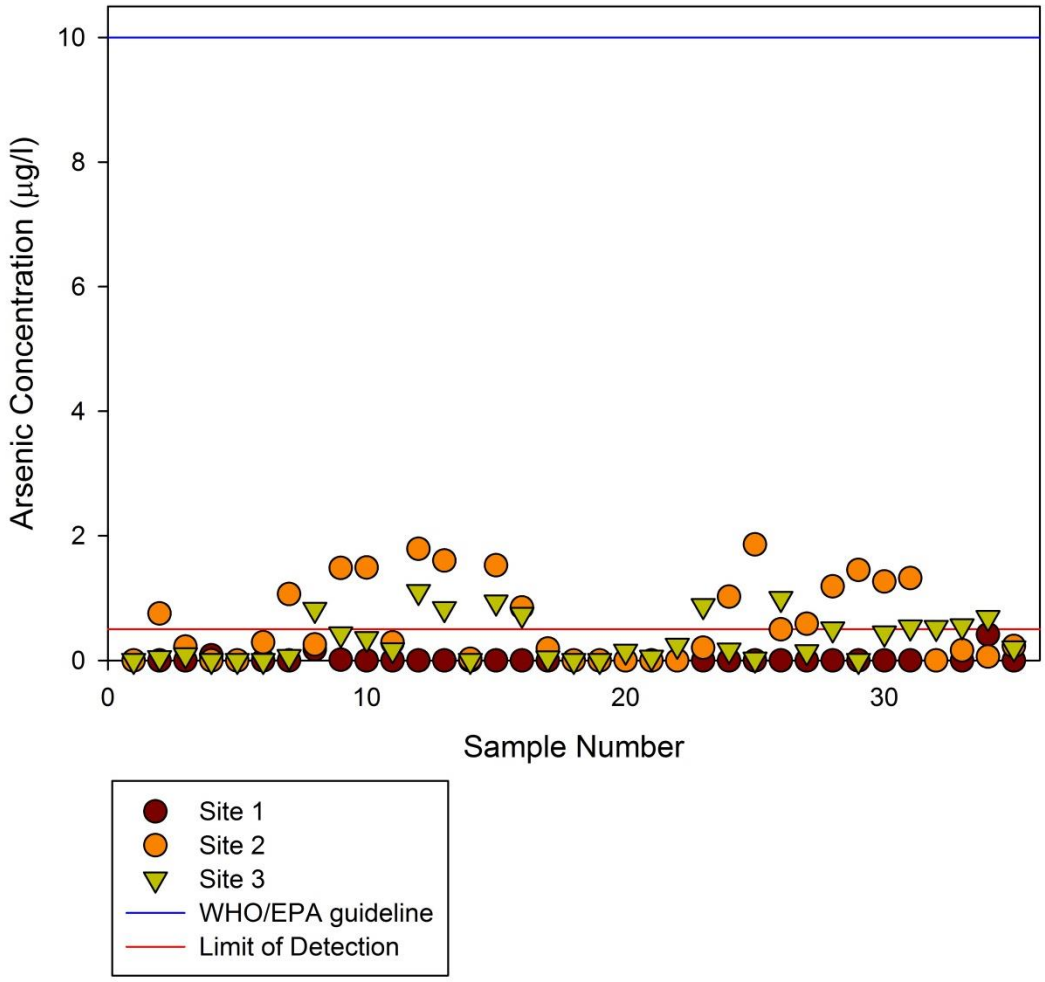


Figure B: Arsenic concentrations in 3 villages

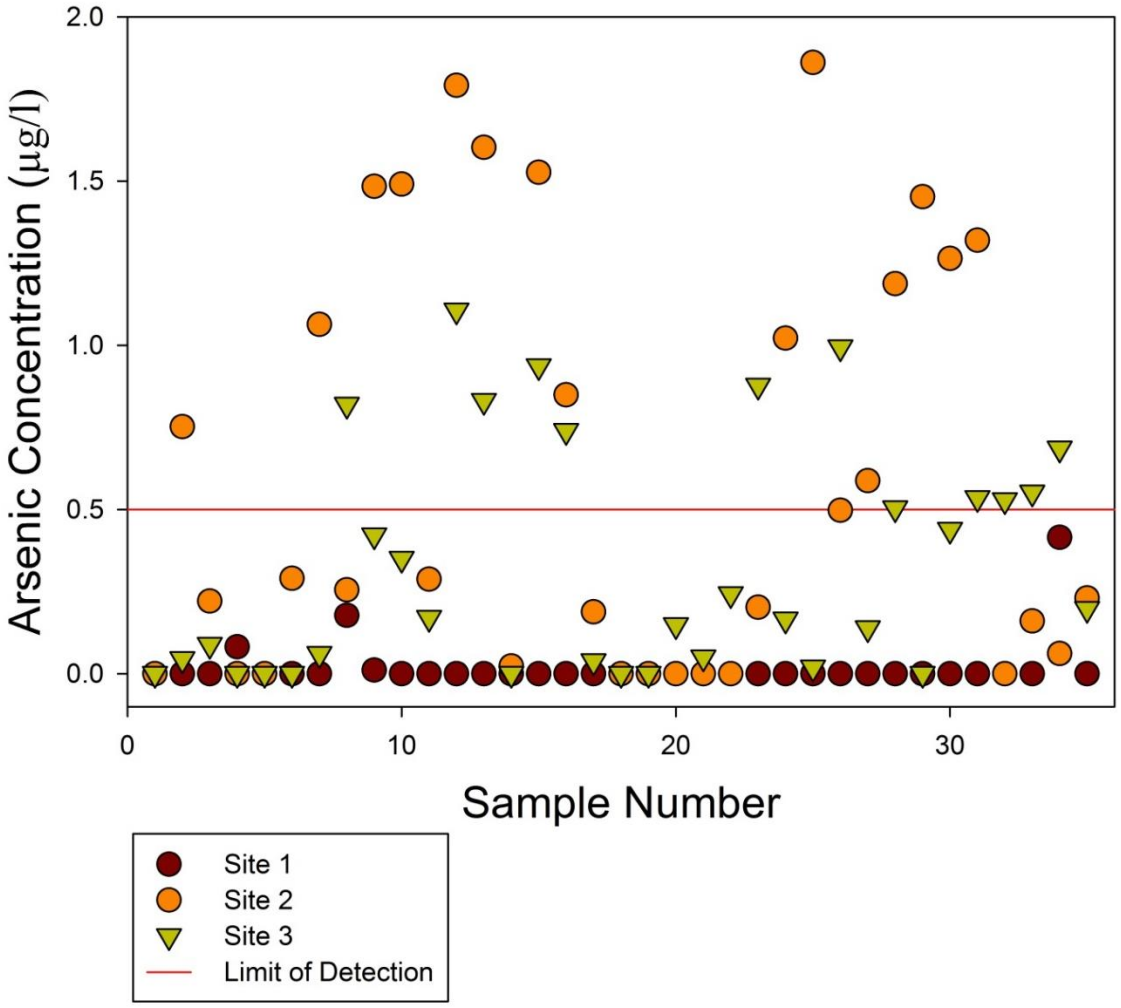


Figure C: Total Dissolved Solids (TDS) in PPM

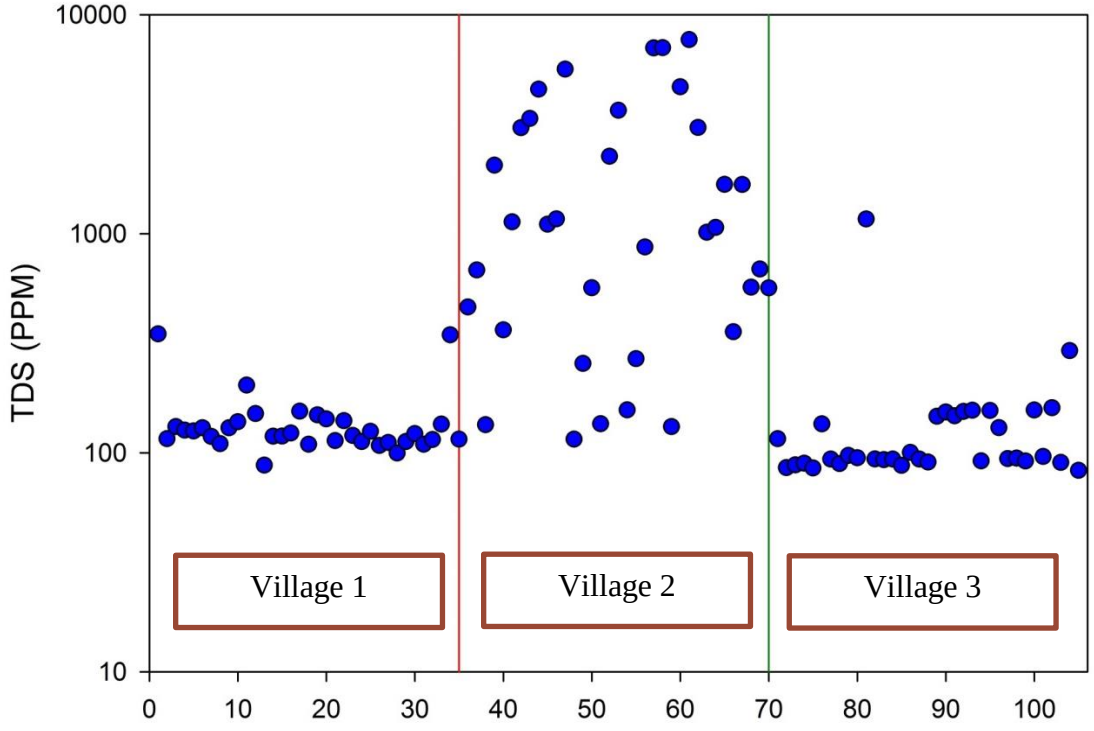
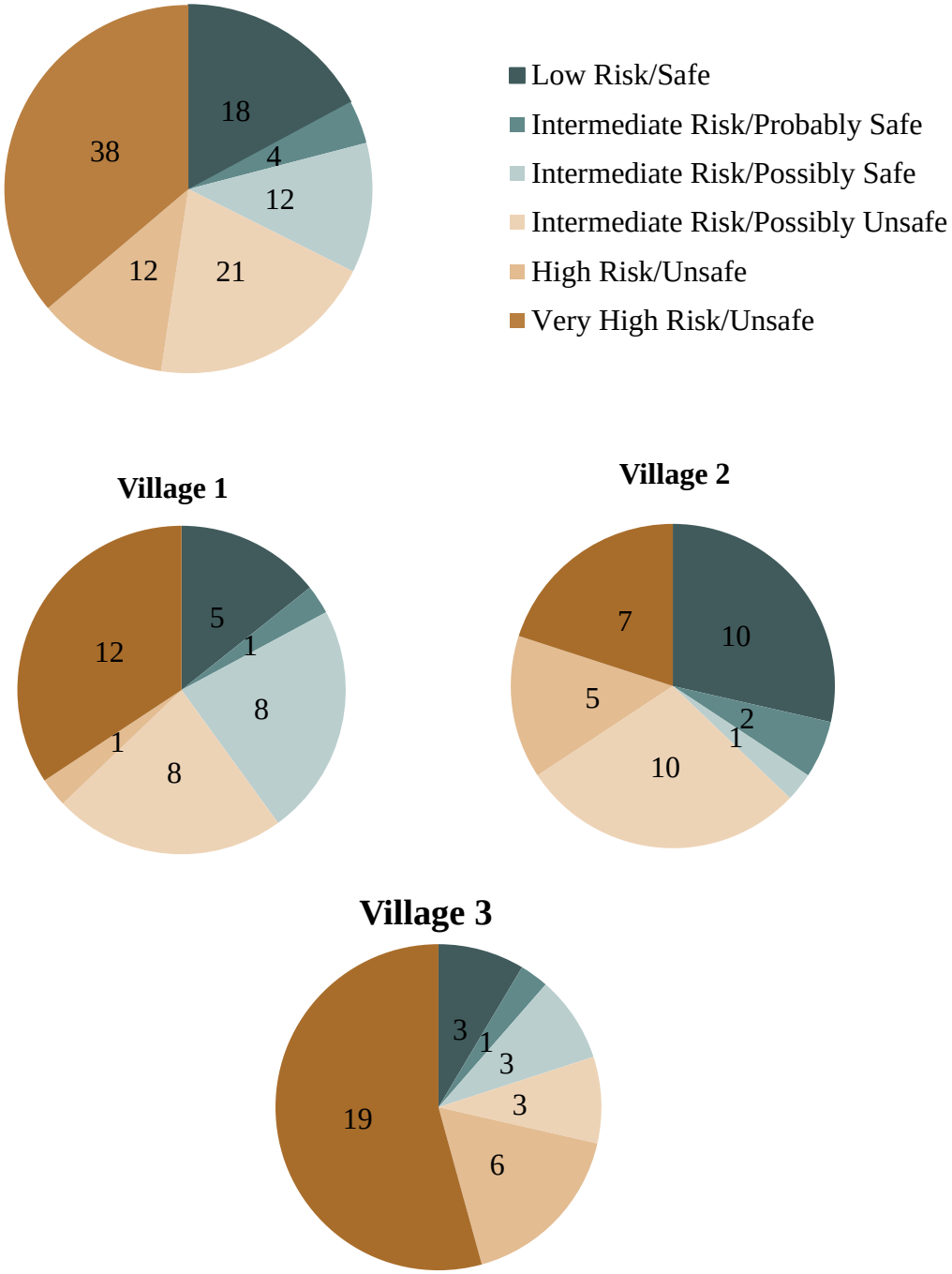


Figure D: *E. coli* risk levels for all samples (n=105) and by village (n=35)



Appendix B Vietnamese Household Survey

Hello. My name is _____. I work with An Giang University. Your household has been randomly selected to be part of our survey of 300 households in the Mekong Delta area. We would like to ask some questions about your drinking water. We will also take some water samples for testing. The questions usually take about 30 minutes. Any information that you provide will be kept completely confidential and your identity will remain anonymous.

Your participation in this survey is completely voluntary and it is your decision if you would like to take part. Your feedback will really help us improve the program and we really appreciate your time and input. If you have any questions regarding this survey, please contact the An Giang staff.

Would you like to participate in this survey?

Date of survey: ___(Date)_____(Month)_____(Year)

Survey start time: ___:___

Survey end time: ___:___

Province/City: _____

District/Provincial Town: _____

Commune/Ward/District Town: _____

I am going to begin by asking some general questions about your household.

1 How many people are in your household? *(If further explanation is needed, ask the following question)* How many people eat from the same cooking pot?

_____ *(Number)*

2 How many children are in your household? *(This refers to all the people living in the household under the age of 18)*

_____*(Number)*

3 How many of the children in your household are under the age of 5? *(If none, record '0')*

_____*(Number)*

4 What year were you born

_____ *(Year)*

5 Do you work outside the home to earn money? *(If NO, circle 1).* If YES, What work do you do?

1...No outside work

2…Handicrafts

3…Harvesting/Farming on Family Land

4…Harvesting/Farming on Neighbor's Land

5…Shop Keeper/Street Vendor

		6…Fishing 7…Salaried worker 00…Other*(Specify)*
6	In the past year, has your family had enough to eat?	1…Yes, all the time 2…No, there was never enough food 3…No, sometimes there was not enough food 99…I don't know
7	What have you produced over the past year? (Circle all that apply)	1… Rice 2…Vegetables 3…Fruit 4…Other Crops 5…Poultry 6… Pigs 7…Fish 0…None of these 99…I don't know
8	What have you bought over the past year? (Circle all that apply)	1… Rice 2…Vegetables 3…Fruit 4…Other Crops 5…Poultry 6… Pigs 7…Fish 0…None of these 99…I don't know
9	What is the highest diploma you have obtained?	0…No diploma 1…Primary school 2… Lower secondary school 3… Upper secondary school 4… Short-term vocational training 5… Long-term vocational training 6… Professional High School 7… Junior College Diploma 8… Bachelor Degree 9… Master Degree 00… Other_____
10	How far away is the local people's community center from your home?	_____Distance in km)
11	How far away is the local market from your home?	_____ (Distance in km)

SECTION 2: Current Water Supply Situation: Example Worksheet

I'd like to start by asking you some questions about the water you currently use. This includes water used for drinking, cooking, washing, and bathing (but not agriculture).

Source		Questions 12.1 -12.16
a. Commercial/ Government Connection	rainy	
	dry	
b. Private wells _____Depth (approximate)	rainy	
	dry	
c. Public taps / Shared wells _____Depth (approximate)	rainy	
	dry	
d. River	rainy	
	dry	
e. Ditch or canal	rainy	
	dry	
f. Spring	rainy	
	dry	
g. Rain Water	rainy	
	dry	
h. Bottled Water	rainy	
	dry	
i. Other _____	rainy	
	dry	

	Answer choices
12.1 Which of the following sources do you ever use during the _____ season?	0. have never used 1. used in the past/ used before 2. currently use/ use now
12.2 Describe the amount of water you obtain from this source?	1. all of it 2. most of it 3. about half 4. less than half 5. only a little 6. used infrequently when main source unavailable
12.3 How many days per week do you collect water from this source?	enter days (range 0-7)
12.4 How many hours per day do you	enter hrs. (range 0-24)

collect water from this source (include waiting time)?	
	Put down numbers for all that apply
12.5 What do you use this source of water for?	1. Drinking 2. Cooking 3. Washing/ bathing 4. Washing clothes 5. Feeding animals 6. Brushing teeth 7. Other (Specify _____)
12.6 If you drink it, How does the water taste?	1. No taste 2. Salty 3. Chemical 4. Other 5. Sweet
12.7 How does the water look in terms of color?	1. clear 2. With color 3. Cloudy
12.8 If you use this water for drinking, do do you think it is safe or unsafe?	1. safe 2. unsafe 99. Don't Know
12.9 Is water available from this source when it's supposed to be?	0. no 1. sometimes 2. yes
12.10 Is there sufficient water for your needs at this source?	1. sufficient 2. not sufficient
12.11 How satisfied are you with this water source?	1. satisfied 2. Somewhat satisfied 3. Not satisfied
12.12 Do you normally treat this water after you collect it?	1. Yes **Skip to question 12.14)** 2. No **(Ask question 12.13)**
12.13 If you do not treat your water, why not?	1. It is safe 2. Don't drink this source 3. It is too expensive to treat 4. Other _____ **(AFTER THIS QUESTION, Move to next section)**

12.14 If Yes, how do you treat this water	1. Let it settle/precipitate 2.Strain it through a cloth 3. Boil 4. Add Chlorine or Iodine 5. Solar disinfection 6. Sand Filter 7. Ceramic Filter 8. Other (Specify)
	1. Yes (**Skip to next section)**
	2. No **(Ask question 12.16)**
12.15 Is your treatment working well?	99. I don't know **(Skip to next section)**
12.16 If this treatment is not working well, why not?	1. Parts are broken 2. It is blocked 3. The water coming out looks cloudy 4. Other (Specify _____)

Current Water Supply Situation Continued: EXAMPLE WORKSHEET

I'm now going to ask you more questions about the water sources you told me you use - these questions address ownership and payment for services.

Source	Questions 12.19 through 12.27
a. Commercial/ Government Connection	
b. Private wells	
c. Public taps / Shared wells	
d. River	
e. Ditch or canal	
f. Spring	
g. Rain Water	
h. Bottled Water	
i. Other _____	

	Answers for Questions 12.19-12.27
12.19 Who owns this water system? (**Don't prompt)**	1. the community or leaders 2. municipality 3. regional government 4. national ministry 5.donor agency 6. NGO 7. Household owns it 99.. I don't know
12.20 Does your household currently pay for water used from this source?	0. no 1. yes **(skip to 12.22)**
12.21 Why don't you pay?	1. there is no tariff - water is free **(skip to page 4 of survey)** 2. nobody collects the tariff 3. we do not receive water bills 4. we paid officials not to collect from us 5. we cannot afford to pay 6. we are not satisfied with the service 7. Other
12.22 How often do you receive a water bill?	0. no receive 1. every month 2. every other month 3. every 3-4 months 4. every 6 months 5. Every year
12.23 How much do you pay to use water from this source (in dong)?	amt. unit unit codes: 1. year 2. month 3. week 4. day 5. Other
12.24 Who do you pay?	1. the community or leaders 2. municipality 3. regional government 4. national ministry 5.donor agency 6. NGO
12.25 Is your household past due on your water bill?	0. no 1. yes
12.26 What is the first thing that happens if the household does not pay its water bill?	0. nothing 1. household is warned that service will be disconnected 2. household is disconnected

	3. household can negotiate payment plan 4. household must pay penalty to continue to use service 5. Never happens, everyone pays 6. Other
12.27 Do you think the amount you are expected to pay is fair for the service you receive?	0. no 1. yes

Section 4

I am now going to ask you how you store and use your water and what type of waste facilities you use

13	Where do you store your drinking water?	1...In containers (bucket, jerry can bottle, drum) 2…Roof tank 3…Does not store water
14	May I see your water storage containers? *Observe: What type of containers are these? (circle one answer only)*	1...Narrow mouthed 2...Wide mouthed 3...Of both types
15	*Observe: Do the water storage containers have lids? (Circle one answer only)*	1...All have lids 2…Only some of the water storage containers have lids 3...None of the water storage containers have lids
16	How do you normally distribute the water from your storage container? *(Circle one answer only)*	1…Dip a cup 2…Pour 3…Tap 4…Other *(Specify)*__ _____
17	Who is the main person in the household who collects water? *(Circle one answer only)*	1...Mother 2...Father 3...Daughter 4...Son 5…House help 00...Other *(specify)*_____ _____
18	Who is the main person in the household who manages the water? (Circle one answer only)	1...Mother 2...Father 3...Daughter 4...Son 5…House help 00...Other*(specify)* _____
19	What kind of toilet does this household have? *(Circle one*	11...Flush/pour-flush toilet 21...Ventilated Pit latrine

	answer only)	22...Simple pit latrine with cement 23...Pit latrine without slab/open pit 24… Latrine constructed over ditch or waterway 26...No facility, field, bush, plastic bag
20	Do you have to repair this toilet after it floods?	1… Never 2… Sometimes 3… Always 99… I don't know
21	Where is the toilet? *(Circle one answer only)*	1...Inside or attached to dwelling 2…In the compound 3...Outside the compound/communal
22	How many households share this toilet?	Number ____ ____
23	May I see the toilet facility please? *Observe access to facility. Are there obstacles in the path? Signs of regular use? (Circle multiple answers if necessary)*	How clean is it on a scale from 1 to 5 _____ (Surveyor writes down number) **1=Very dirty, 2= Somewhat dirty 3=A little dirty 4=Somewhat clean 5=Very clean** Does the latrine have a lid? 1...Yes 2.No
24	Can you show me where you usually wash your hands? *(Circle one answer only)*	1...Inside/near toilet 2...Inside/near kitchen/cooking place 3...Elsewhere in yard 4...Outside yard 5...No specific place 8...No permission to see
25	How many times per day do you wash your hands	_____ Number per day
26	When do you wash your hands with soap? *(Circle multiple answers)*	1…After using the restroom/bathroom/latrine 2…After changing babies dipers 3…Before handling food 4…Before handling drinking water 5… After handling livestock/fish 6…After laboring in the field 7…Other_____ 8…Never

Section 5

The next set of questions will ask about your local community

27	Are there any active committees or groups in the community that relate to drinking water?	1… Yes _____ (Specify Type and how many) 2…. No **Skip to Question 31** 99… I don't know **Skip to Question 31**
28	How were they formed?	1… Started on their own 2… Had assistance from an NGO 3… Had assistance from local government 4… Is a local government committee 99… Don't Know 00… Other _____ (specify)
29	Are you an active member of any of these groups?	1… Yes 2… No 99… Don't Know
30	How often is there communication between the district level government and this community?	1… Never 2… Only when we need to 3… Regularly - Every 6 months 4… Regularly- monthly 99… Don't Know 00… Other _____ (specify)
31	During the year, is there any time that is difficult to collect or buy drinking water?	1.. Yes 2.. No **(Skip to question 34)** 99.. I don't know
32	If yes, What time of year is the most difficult?	1…Rainy Season 2… Dry Season 00…Other _____ (specify)
33	If yes, why is it difficult to collect or buy drinking water?	1… truck or tank can not come 2… The flood waters are too high to travel 3… It does not rain enough 4… It is too expensive 5… The well does not have water 6… It is difficult to walk to the water source 00… Other _____ (Specify)

Section 6: Climate Change

I am now going to ask you questions about the weather and climate

34	Have you noticed any long-term changes in the temperature over the last 20 years?	1… Yes 2… Know 99… I don't know
35	Has the number of hot days stayed the same, increased, or decreased over the last 20 years?	1… Increased 2… Decreased 3… Stayed the same 99… I don't know
36	Have you noticed any long-term changes in the total rainfall over the last 20 years?	1… Yes 2… No 99… I don't know
37	Has the number of rainfall days stayed the same, increased or declined over the past 20 years?	1… Increased 2… Decreased 3… Stayed the same 99… I don't know
38	Have you noticed any long-term changes in the salinity of water used for farming over the last 20 years?	1… Increased salinity 2… Decreased salinity 3… Stayed the same 99… I don't know
39	**FOR FARMERS ONLY** Have you made any adjustments in your farming practices over the past 20 years because of the change in temperature or rainfall?	1… Yes 2… No 99… I don't know
40	**FOR FARMERS ONLY** If yes, what changes have you made? (circle all that apply)	1… Change crop variety 2… Built a water dyke 3… Buy insurance 4… Put trees for shading 5… Irrigate more 6… Change from crop to livestock 7… reduce number of livestock 8… Find work in urban area 9… Find work in local area (not farming) 10… lease your land to another farmer 00… Other _____

_____

41	Do you have any questions for us? *(Record all mentioned)*
42	*Other comments, observations and notes by the surveyor…*
	Remember to thank the respondent for his/her time!

Appendix C: Online Survey

Default Question Block

Purdue University is conducting a survey to identify the organizations and stakeholders working in the Mekong River Basin. Through our research, we aim to map the resource management network and identify basin priorities of the Mekong River Basin. We are interested in your input as a stakeholder in the basin. We would like to ask some questions about general stakeholders and environmental concerns in the Mekong River Basin in addition to your perceptions about a specific set of organizations working in the Mekong.

Your participation is completely voluntary. Your answers will be kept confidential and will be released only as summaries where individual answers cannot be identified. The questions you will be asked have been approved by the Institutional Review Board of Purdue University. You may skip any questions that you are uncomfortable answering.

This survey should take 15-20 minutes to complete. We would like to sincerely thank you for your time and we look forward to hearing your valuable input. If you have any questions or concerns please contact Caitlin Grady at grady3@purdue.edu. Hampton Hall, Purdue University 550 Stadium Mall Drive, West Lafayette IN 47907.

Would you like to participate in this survey?

- Yes
- No

Block 1

How long have you been working on resource management of the Mekong Basin (total time, not just at current position)?

- Less than 1 year
- 1 year to 5 years
- Between 5 and 10 years
- 10 years or more

How long have you lived in the region (Lao PDR, Thailand, Vietnam, China, Cambodia)?

- Less than 1 year
- 1 year to 5 years
- Between 5 and 10 years
- 10 years or more
- 10 years or more and I am a native citizen to one of the countries listed

Which countries do you work in? (please check all that apply).

- Cambodia
- China (Yunnan Province)
- Lao PDR
- Myanmar (Burma)
- Thailand
- Vietnam

Which part of the Mekong Basin do you work in?

- Upper Mekong Basin
-

Lower Mekong Basin

- Both Upper and Lower Mekong Basin

Which organization is your primary place of employment?

Have you attended any of the annual Mekong Forums on Water, Food and Energy?

- Yes
- No

If yes, how many?

- One
- Two
- Two and I plan to attend the third this year

If not, why not?

What other professional conferences do you attend for information on the Mekong River Basin?

What are your TWO most preferred methods for receiving information about the Mekong (please select only 2)?

- Journal articles
- Emails
- Scientific websites
- Presentations at meetings
- News reports
- Technical Reports
- Colleagues in my organization- verbal communication
- Colleagues outside of my organization- verbal communication
- Citizens and/or farmers in the Mekong Basin
- Other, please specify

What are your TWO most frequent sources of information (please select only 2)?

- Journal articles
- Emails
- Scientific websites
- Presentations at meetings
- News reports
- Technical reports
- Colleagues in my organization- verbal communication
- Colleagues outside of my organization- verbal communication
- Citizens and/or farmers in the Mekong Basin
- Other, please specify

Do you believe there is research available that could affect the Mekong River Basin management that has NOT been made easily available?

- Yes
- No

In your opinion, what currently unavailable information/research would be most useful for managing the Mekong River Basin (please specify up to three topics)?

The next set of questions pertain to your involvement as a partner organization associated with the the Challenge Program on Water and Food (http://mekong.waterandfood.org/). This program has listed you as a collaborator on their research and projects throughout the Mekong Basin. Please answer all questions completely and truthfully to the best of your ability. Your individual responses will be kept confidential and only described as a group when reporting these findings.

Has the Challenge Program on Water and Food Mekong asked you about your priorities in terms of watershed management for the Mekong?

- Never
- Rarely
- Yes, sometimes
- Yes, often

Does this group ask about your knowledge of the Mekong Basin?

- Never
- Rarely
- Yes, sometimes
- Yes, often

Have you seen researchers from the CPWF incorporate any of your knowledge into their research projects, reports or research design?

Never	Rarely	Yes, sometimes	Yes, often
○	○	○	○

Are the researchers from the CPWF meeting your needs as a manager/decision-maker in the Mekong Basin?

Yes, fully	Yes, partially	No
○	○	○

Please rate the following statements according to how much you agree or disagree with the statements.

This group facilitates discussions about the Mekong Basin threats and priorities among your group and other groups in the region:

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

This group is a powerful networking initiative in the Mekong Basin

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

○	○	○	○	○

This group brings together actors who would not normally work together

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

A program similar to the Challenge Program would be important in the future

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

What do you think this program's strengths are?

What do you think this program's weaknesses are?

The following list contains organizations that have been identified as participants in Mekong River Basin management. Please check the following organizations that are:

a. other organizations that you formally report to, collaborate with, or work with on watershed management in the Mekong
b. other organizations that you have an informal professional relationship with (e.g. which organization has professionals that you would call if you had a Mekong Basin management question)
c. other organizations that you are familiar with but have had no formal or informal interactions with
d. other organizations that you do not know if they are working in the Mekong Basin (e.g. you have not heard of them)

	A) Formally report to, collaborate, or work with (Please check all that apply)	B) Have an informal professional relationship with (Please check all that apply)	C) Familiar with but have no formal or informal interaction (Please check all that apply)	D) Unknown working in the Mekong Basin (Please check all that apply)
Asian Development Bank	☐	☐	☐	☐
Advocacy and Policy Institute of Cambodia	☐	☐	☐	☐
Asian Institute of Technology	☐	☐	☐	☐
AusAID	☐	☐	☐	☐
Cambodia Development Research Institute	☐	☐	☐	☐
Cambodia National Mekong Committee	☐	☐	☐	☐
Cambodian Center for Study and Development of Agriculture	☐	☐	☐	☐
Cambodian Consulting Development Engineering	☐	☐	☐	☐

Cambodian Institute of Technology	☐	☐	☐	☐
	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)
Center for Development Oriented Research in Agriculture and Livelihood Systems(CENDOR)	☐	☐	☐	☐
Center for Sustainable Development of Water Resources and Adaptation to Climate Change	☐	☐	☐	☐
Center for Water Resources Conservation and Development	☐	☐	☐	☐
Central Institute for Economic Research and Management, Ministry of Planning and Investment	☐	☐	☐	☐
Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement (CIRAD)	☐	☐	☐	☐
Chaing Mai University	☐	☐	☐	☐
Challenge Program on Water and Food Mekong Basin	☐	☐	☐	☐
Chulalongkorn University	☐	☐	☐	☐
Consultancy on Development	☐	☐	☐	☐
	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	☐	☐	☐	☐
Culture and Environment Preservation Association	☐	☐	☐	☐
D Foundation for Doing Good Work	☐	☐	☐	☐
Department of Environmental Science, Royal University of Phnom Penh	☐	☐	☐	☐
East Forum Cooperation Centre	☐	☐	☐	☐
Electricite du Laos	☐	☐	☐	☐
Enterprise Development Institute	☐	☐	☐	☐
Food and Agriculture Organization (FAO)	☐	☐	☐	☐
Government Agency (Cambodia) Please specify ministry and department or program:	☐	☐	☐	☐

	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)
Government Agency (Lao PDR), Please specify Ministry and Department or Program:	☐	☐	☐	☐
Government Agency (Thailand), Please specify Ministry and Department or Program:	☐	☐	☐	☐
Government Agency (Vietnam), Please specify Ministry and Deparment or Program:	☐	☐	☐	☐
Green Watershed	☐	☐	☐	☐
Green ID	☐	☐	☐	☐
Hatfield Consultants	☐	☐	☐	☐
International Center for Environmental Management	☐	☐	☐	☐
International Finance Corporation	☐	☐	☐	☐
International Rivers	☐	☐	☐	☐

	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)
International Water Management Institute	☐	☐	☐	☐
IUCN	☐	☐	☐	☐
King's College	☐	☐	☐	☐
Lao Institute for Renewable Energy	☐	☐	☐	☐
Lao Water Resource Network	☐	☐	☐	☐
Mekong Development Centre	☐	☐	☐	☐
Mekong Program on Water, Food and Resilience (M-Power)	☐	☐	☐	☐
Mekong River Commission	☐	☐	☐	☐
Nam Theun - Nam Kading River Basin Committee Secretariat	☐	☐	☐	☐

	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)
Nam Theun 2 Power Company	☐	☐	☐	☐
National Research Center for Resettlement, Hohai University	☐	☐	☐	☐
National University of Laos	☐	☐	☐	☐
Natural Heritage Institute	☐	☐	☐	☐

Oxfam Australia	☐	☐	☐	☐
Palang Thai	☐	☐	☐	☐
PanNature	☐	☐	☐	☐
Participatory Development Training Center	☐	☐	☐	☐
Peking University	☐	☐	☐	☐
	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)
Theun Hinboun Power Company	☐	☐	☐	☐
Tonle Sap Authority	☐	☐	☐	☐
Ubon Ratchathani University	☐	☐	☐	☐
University of Sydney	☐	☐	☐	☐
Vietnam Electricity	☐	☐	☐	☐
Vietnam University of Science	☐	☐	☐	☐
Village Focus International	☐	☐	☐	☐
Waratah Power	☐	☐	☐	☐
Western Highlands Agro-Forestry Scientific & Technical Institute	☐	☐	☐	☐
	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)	(Please check all that apply)
WorldFish	☐	☐	☐	☐
World Wildlife Fund (WWF)	☐	☐	☐	☐
Yunnan University	☐	☐	☐	☐
Other non-state (non-profit) organizations, please specify:	☐	☐	☐	☐
Other state or government organizations, please specify:	☐	☐	☐	☐
Other corporate organizations or companies, please specify:	☐	☐	☐	☐
Other university organizations, please specify:	☐	☐	☐	☐

Which of the following does your work most directly address?

- ○ Climate change
- ○ Habitat loss
- ○ Industrial contamination
- ○ Invasive species
- ○ Agriculture: Non-point source nutrient loading
- ○ Agriculture: Farming practices
- ○ Agriculture: Other

- Hydrology: Fisheries management
- Hydrology: Water allocation
- Hydrology: Other
- Large scale infrastructure projects
- Governance
- Community-based natural resource management
- Other:

From the following list, please give your personal perception of what topic is being most **SUCCESSFULLY** managed in the Mekong River Basin?

- Climate change
- Habitat loss
- Industrial contamination
- Invasive species
- Agriculture: Non-point source nutrient loading
- Agriculture: Farming practices
- Agriculture: Other
- Hydrology: Fisheries management
- Hydrology: Water allocation
- Hydrology: Other
- Large scale infrastructure projects
- Governance
- Community-based natural resource management
- NONE of these are being sustainably managed
- Other:

From the following list, please give your personal perception of what the greatest THREAT to the **ENVIRONMENTAL sustainability** of the Mekong River Basin?

Environmental sustainability refers to the long term health of ecosystems (rivers, forests, jungles, etc) within the Mekong Basin

- Climate change
- Habitat loss
- Industrial contamination
- Invasive species
- Agriculture: Non-point source nutrient loading
- Agriculture: Farming practices
- Agriculture: Other
- Hydrology: Fisheries management
- Hydrology: Water allocation
- Hydrology: Other
- Large scale infrastructure projects
- Governance

- Community-based natural resource management
- NONE of these are a threat to sustainability
- Other:

From the following list, please give your personal perception of what the greatest THREAT to the **sustainability of LIVELIHOODS** in the Mekong River Basin?

Livelihood sustainability refers to the long term health and success of people and communities who live within the Mekong Basin

- Climate change
- Habitat loss
- Industrial contamination
- Invasive species
- Agriculture: Non-point source nutrient loading
- Agriculture: Farming practices
- Agriculture: Other
- Hydrology: Fisheries management
- Hydrology: Water allocation
- Hydrology: Other
- Large scale infrastructure projects
- Governance
- Community-based natural resource management
- NONE of these are a threat to sustainability
- Other:

Do you have any other questions, comments, or concerns?

VITA

VITA

Education

Purdue University — May 2015
Doctor of Philosophy (PhD) Ecological Sciences and Engineering Program
Lyles School of Civil Engineering, GPA 3.9

Purdue University — December 2011
Masters of Science (MS) Ecological Sciences and Engineering Program
Agricultural and Biological Engineering Department, GPA 3.9

Virginia Polytechnic Institute and State University — May 2010
Bachelors of Arts in Humanities, Science, and the Environment (HSE)
Minor in Environmental Policy and Planning, GPA 3.8

Professional Experience

– **Purdue University Ecological Sciences and Engineering Program**
National Science Foundation Graduate Research Fellow
June 2012 – May 2015

– **Purdue University Women in Engineering Program**
Graduate Mentoring Program Staff
March 2011 – May 2014
Access Engineering Staff
May 2013 – August 2013 and May 2014 – August 2014

– **Purdue University School of Civil Engineering**
Teaching Assistant and Guest Lecturer, multiple courses
August 2011- May 2013

International Experience

– Southeast Asia; Lao PDR, Thailand, Vietnam, Cambodia — 2013-2014
- Doctoral research activities

– East Africa: Kenya, Tanzania, Uganda — 2012-2013
- AMPATH Family Preservation Initiative community outreach internship
- Doctoral research activities

– Middle East: Jordan, Israel, The Palestinian Authority, and Egypt — 2011
- US Department of State office of Citizen Exchange Fellowship

– Central America and Caribbean: Dominican Republic, Honduras — 2008-2010
- Undergraduate research activities

Select Academic Awards and Research Grants

National and International Awards

– U.S. Borlaug Global Food Security Graduate Research Award
– Challenge Program on Water and Food; Opportunity Fund Award
– Next Generation Delegate for the Chicago Council Global Food Security Symposium
– National Science Foundation Graduate Research Fellowship
– U.S. Borlaug Summer Institute on Global Food Security
– Across Borders Fellow, US Department of State. Early Career Award to Study Trans-Boundary Environmental Resources in the Middle East and the US

Institutional and Regional Awards

– Most Outstanding Interdisciplinary Project Award, Purdue University
– Best Student Presentation Award. Indiana Lakes Management Society Annual Conference
– Andrews Environmental Travel Grant at Purdue
– Purdue University Lynn Fellowship

Service

Professional Affiliations

– American Association for the Advancement of Science (AAAS)
– Society of Women Engineers (SWE)
– American Academy of Environmental Engineers (AAEE)
– American Society of Civil Engineering (ASCE)

Community Outreach Activities

– Lyn Treece Boys and Girls Club: Keystone Kids Garden Club
– Team in Training for the Leukemia and Lymphoma Society
– Agricultural and Biological Engineering Graduate Student Association
– Ecological Sciences and Engineering Annual Symposium Planning Committee
    - Logistics Chair and Poster Session Coordinator: Mar. 2011-Mar. 2012

PUBLICATIONS

PUBLICATIONS

Grady, C.A.; Kipkorir. E.; Nguyen, K.; and Blatchley III, E.R. 2014. Microbial quality of improved drinking water sources: Evidence from western Kenya and southern Vietnam. *Journal of Water and Health. In Press.* doi:10.2166/wh.2014.206

Grady, C.A.; He, X.Z.; and Peeta, S. 2015. Integrating social network analysis with analytic network process for international development project selection. *Expert Systems with Applications.* 42(12): 5128–5138.

Grady, C., A. P. Reimer, J. R. Frankenberger, and L. S. Prokopy. 2013. Locating existing Best Management Practices within a watershed: The value of multiple methods. Journal of American Water Resources Association. 49(4): 883-895.

Grady, C. and T. Younos. 2012. Bottled Water Technology and Its Global Ramifications: An Overview. International Water Technology Journal. 2(2):185-195.

Younos, T. and **C. Grady** *eds.* 2014. Potable Water: Emerging Global Problems and Solutions. The Handbook of Environmental Chemistry. Springer Publishing. ISBN 978-3-319-06562-5.

Grady, C., S.C. Weng, and E.R. Blatchley III. 2014. Global potable water: current status, critical problems and future perspectives. In *Potable Water: Emerging Global Problems and Solutions. The Handbook of Environmental Chemistry.* Springer Publishing. 37-60.

Younos, T., and **C. Grady** *eds.* 2013. Climate Change in Water Resources. The Handbook of Environmental Chemistry, Vol 25. Springer Publishing. ISBN: 978-3-642-37585-9.

Chen, Y.S., L. Li, L. Jiang**, C. Grady**, and X.H. Li. 2013. The Impact of urban water use on energy consumption and climate change: A case study of household water use in Beijing. In *Climate Change in Water Resources. The Handbook of Environmental Chemistry*. 169-197.