The Return on Investment from GCC Climate Change-Related Disaster Risk Reduction Projects

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Distribution

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Abstract

The United States Department of Defense engages in numerous humanitarian and development assistance projects around the world. The Army Corps of Engineers asked CNA to examine means of evaluating the return on investment of the climate-related disaster-risk-reduction projects that the military undertakes. Increasing these activities may reduce the number and/or size of disaster response missions for the military in the future. We conducted a proof-of-concept study investigating whether data and methods exist to estimate the return on investment. We built upon many related analyses that have been conducted for the civilian sector. We outlined and tested two basic approaches, and extracted lessons regarding the viability of the approaches, the utility of the results, and means to improve the implementation of the analytic approach.

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Executive Summary

The United States Department of Defense engages in numerous humanitarian and development assistance projects in nearly 200 countries around the world, at a cost of over $50,000,000 a year. Many of these projects are disaster risk reduction (DRR) activities that aim to reduce the risk of damage from climate-related disasters, such as floods, storms, droughts, intense heat waves, and related agricultural stress. Currently, DOD is interested in evaluating the return on investment (ROI) of the climate-related DRR projects that the U.S. military conducts. Increasing DRR activity may reduce the number and/or size of disaster response missions that U.S. military forces will need to perform in the future, and save money over the long term. DRR efforts can also create savings in affected countries due to fewer deaths, less damage to property, and reduction in the stresses that can lead to social unrest after disaster strikes.

There is a large literature evaluating the ROI for DRR projects in the civilian sector. For the most part, the metrics in this literature pertain to gains related to fewer casualties and limiting or mitigating property damage and the effects of disasters on the affected countries' gross national product, economic productivity, etc. To our knowledge, however, there has been no analysis to date on estimating the ROI of military DRR projects—either in terms of direct cost savings to DOD due to being tasked with fewer or smaller DR missions, or in terms of improvements in the resiliency of the foreign nations and populations. So, we conducted a proof-of-concept study investigating whether data and methods exist to estimate ROI for DOD climate-related DRR projects, and defined a path forward to extend the analysis.

We developed and examined two methods to estimate the ROI of these DRR projects. The methods and data draw on the costs of past DRR projects and the cost and frequency of past DOD DR missions, as well as the frequency of disasters in foreign countries and the number of people they affect. The first method is based on case studies, which are before-and-after comparisons of the situation before a project is implemented and after. We computed some preliminary ROI estimates for a few specific types of projects.

In our preliminary estimates, we do find evidence that DOD's DRR projects reduce the number and size (in terms of days of operations, number of sorties, etc.) of disaster relief (DR) missions that DOD performs. Reducing the number and size of the missions reduces the amount of money DOD spends on these missions.

Nonetheless, what is still uncertain is how often these savings from having to do fewer DR missions are high enough to offset the cost of doing the DRR project. In one case study, we analyzed a series of training projects that appear likely to save much more money in DR mission costs than the cost of the project. However, in another series of cases, for road building, it appears the projects likely would generate much less savings in DR mission costs than the cost of the projects. Future work could do more case studies of additional types and instances of DRR projects and use additional sources of data, such as the official DOD cost model for generating cost estimates of contingency operations such as DR missions (namely, the Institute for Defense Analyses' COST model), to improve the accuracy of the estimates.

The analysis is complicated by the fact that many theater security cooperation (TSC) and DR activities are conducted for a variety of reasons, and the U.S. forces deployed may have multiple tasks. Estimating the reduction in DR mission costs caused by DRR projects is complicated by the facts that major disasters likely will generate a significant (and international) response in any case; and that the U.S. may respond to smaller disasters to "show the flag" or "promote good will" even if the physical environmental conditions don't necessarily require additional outside support. Furthermore, the full scope and spectrum of benefits of DRR and other TSC activities, which include benefits besides just reductions in DR mission costs, are difficult to capture because U.S. development activities are intended to be coordinated and aligned with broader, complex U.S. policies and goals. Also, the U.S. military contributions add up to just a small fraction of the overall U.S. development activity efforts, which include U.S. Agency for International Development efforts. Thus, care must be taken in interpreting the available data.

The second method that we outline involves using data from the Notre Dame Global Adaptation Index (ND-GAIN), which provides numerous measures of the vulnerability of countries to the effects of climate change. The basic assumption is that DRR projects improve the measures in this index, thereby reducing vulnerability and the likelihood of the country requiring outside support when dealing with disaster events. We show that improved measures in the ND-GAIN index variables have statistically significant associations with better climate disaster-related outcomes in terms of DOD being tasked with shorter DR missions, as well as fewer deaths caused by disasters and fewer persons being affected by disasters. Future research could use this method to estimate ROI by estimating how much different types of projects with different costs improve the index and correlating the index data with DOD spending in countries on conducting disaster relief missions, as well as spending by these countries' governments and civilian-sector NGOs on disaster relief.

We recommend improvements to DOD data collection and management (as part of the OHASIS database) to support obtaining better ROI estimates going forward, for example, additional data on project scale—such as the number of persons served by projects. This enhancement would make it feasible to estimate the ROI of individual projects with statistical approaches like the second method outlined above, rather than just estimating the average ROI across projects within a category. Although we can estimate the average ROIs of different categories, the civilian-sector literature cautions against prioritizing projects by category alone. This is because ROIs have been found to vary greatly between different projects within the same category, and also within the same country. We recommend DOD prioritize projects based on ROI estimates specific to individual projects whenever feasible.

Finally, the review of the literature on the ROI of civilian-sector DRR projects found the positive result that many, if not most, DOD DRR projects are likely to have good ROI in terms of benefits to the host nations—the projects create savings by reducing deaths, property damage, injuries requiring medical care, and the number of persons who require emergency assistance after disasters. Many DOD DRR projects are similar in nature to those done by the civilian sector, and the large literature on civilian-sector DRR efforts has found that about 85 percent of the projects it has evaluated have reasonably promising benefit-to-cost ratios. So, regardless of what operational savings DOD recoups from doing DRR projects, the military can be confident that its DRR efforts are benefiting the affected host nations.

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Glossary

COST	Contingency Operation Support Tool
DOD	Department of Defense
DR	Disaster Relief
DRR	Disaster Risk Reduction
GCC	Geographic Combatant Command
HA	Humanitarian Assistance
HA/DR	Humanitarian Assistance/Disaster Relief
HCA	Humanitarian Civic Assistance
HN	Host Nation
IDA	Institute for Defense Analyses
NGO	Non-governmental organization
ODI	Overseas Development Institute
OFDA	Office of Foreign Disaster Assistance
OHASIS	Overseas Humanitarian Assistance Shared Information System
OHDACA	Overseas Humanitarian, Disaster Assistance, and Civic Aid
ROI	Return on Investment
TSC	Theater Security Cooperation
TSCMIS	Theater Security Cooperation Management Information System
USACE	United States Army Corps of Engineers

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Introduction

Background

The United States Department of Defense (DOD), through its Services, Agencies, and Geographic Combatant Commands (GCCs), engages in numerous humanitarian and development assistance projects in nearly 200 countries around the world [1-2]. Over 1,500 such projects totaling over $400,000,000 in cost to DOD across all projects have been completed over the past six fiscal years in countries outside the United States [2]. Many of these projects are Disaster Risk Reduction (DRR) activities, and many of these DRR projects reduce the risk of damages from climate-related disasters such as floods, storms, droughts, intense heat waves, and related agricultural stress. Examples of climate-related DRR projects include: building disaster shelters for communities that currently adequate lack shelter in the event of a natural disaster; evaluating whether a site is a suitable place to build an airfield that could be used in Humanitarian Assistance/Disaster Relief (HA/DR) efforts; building and improving roads to remote villages so they are more easily accessible by vehicle before and after a disaster; DOD providing helicopter rescue system and maintenance training to foreign air forces; and DOD engaging in logistical planning with a partner nation about how to more efficiently conduct multinational DR efforts after typhoons in the future. Climate-related disasters are expected to be more frequent and severe in the future due to climate change [3-4], so increasing or at least maintaining the amount of climate-related DRR projects that DOD does may be advantageous.

Currently DOD is interested in evaluating the return on investment (ROI) of the climate-related DRR projects that it conducts outside the United States. DRR projects can save DOD money because DOD is frequently tasked with conducting or assisting with Humanitarian Assistance and Disaster Relief (HA/DR) missions to respond to natural disasters in foreign countries [3]; increasing DRR activity may reduce the number and/or size of HA/DR missions that DOD needs to perform in the future [5]. This preventative effect is a stated rationale for DOD's Overseas Humanitarian, Disaster Assistance, and Civic Aid (OHDACA) Humanitarian Assistance (HA) projects: "… enabling the COMCDRs to assist countries by improving local crisis response capacity and training in disaster planning and preparedness which minimizes the potential for crises to develop or expand, *thereby* promoting regional stability and *reducing a requirement for large-scale deployment of U.S. military forces at a later date.* Such activities include assessment of needs, education support, health-related projects, disaster preparedness and basic infrastructure support [5]" (italics added). DRR efforts can also create savings that are accrued by the countries in which disasters occur: after the DRR projects, the countries may suffer fewer deaths, fewer dollars of damages to property and land, and have less social unrest after disaster strikes than they otherwise would have [6-7].

In response to ongoing demand from policy-makers and decision makers for analysis to determine the economic benefits of DRR activities, there have been over 60 studies estimating the ROI of different specific DRR projects done by civilian sector entities in terms of cost of conducting the project compared with the expected or realized benefits to the countries in which the projects were done [6]. Numerous analysts argue that the civilian sector should be spending more on DRR because the expected ROI to additional investment from the civilian sector is believed to be high at this time [7]. Nonetheless, to our knowledge, no analysis has been done to date on estimating the ROI of DOD's many DRR projects—either in terms of cost savings to DOD on being tasked with doing fewer and/or smaller HA/DR missions in foreign countries, and/or savings to the foreign countries in which DOD does DRR projects themselves [1-2].

Tasking

The U.S. Army Corps of Engineers (USACE) Geospatial Research Laboratory asked CNA to begin the process of estimating the ROI of DOD's disaster risk reduction (DRR) projects that are related to climate disasters and climate change. This report documents a proof-of-concept study to define a path forward for future analysis. It focuses on identifying data sources and developing methods and metrics that can be used to estimate the ROI of DOD's DRR efforts, including how to estimate which specific individual projects and which categories of projects are likely to have higher ROI than others, so that these project- and category-level estimates can be used to prioritize projects. In addition, we computed some preliminary ROI estimates of a few specific projects and found some evidence on what the ROI of climate DRR projects in general is using the data, methods, and metrics we identified.

More specifically, for this analysis:

(1) We conducted a literature review to:
  - Characterize the types of Theater Security Cooperation (TSC) activities geographic combatant commanders (COCOMs) conduct in foreign countries, to identify which of these activities help partner

nations build the capacity and capability to mitigate the damages from climate- and climate-change-related natural disasters. Further, to place different types of projects related to climate disaster damage mitigation into categories as appropriate.

- Review previous attempts to assess the value of these activities

(2) We estimated the costs of:

- Having GCCs conduct different types of climate-related DRR activities
- Having DOD conduct Disaster Relief (DR) operations to respond to different types of climate–related disasters after the disasters occur. In estimating these costs we:
  - Consider the historical record of how often disasters have occurred and how frequently and to what extent DOD has responded to them
  - Also, consider future scenarios based on projections of how climate change may cause disasters to be more frequent and/or severe in the future

(3) We developed ROI methods and metrics and implement them to produce preliminary estimates of the ROI of climate-related DRR activities

- The ROI estimates are based on cost estimates collected in Task 2
- In this study the main focus is on the ROI to US DOD in terms of reductions in the number and/or size of DR missions needed to respond to climate disasters abroad, rather than on quantifying reductions in numbers of deaths, injuries, persons made homeless by disasters, dollars of damage to property and land, etc. in the foreign nations in which the projects are conducted
- We also consider different categories of DRR activities and investigate whether it is feasible and desirable to assess which categories of activities have higher average ROIs than others (according to the average ROI across projects in the category)
- Finally, we make recommendations on what additional types of information and data (if any) DOD would need to collect to generate more refined estimates of ROI of DRR activities in future work

Organization of the report

The first section reviews prior literature on estimating the returns from investment (ROI) of DRR projects. It describes the results of our search for prior literature that evaluates the returns of DRR projects done by DOD, and also reviews the literature that evaluates the returns of civilian-sector DRR projects. Because the civilian-sector literature has done extensive analysis on whether and when it makes sense to prioritize projects by project category, as opposed to forecasting the returns to proposed individual projects and choosing projects based on their forecasted individual returns, we also discuss this issue in this section of the paper.

The second section describes the different categories of DRR projects that DOD does, and presents the available data on how much it costs DOD to do them. Because this section describes the cost data on projects by category, we also describe methods of how one would go about estimating the average-across-projects-within-a-category ROI of different categories of projects in this section. Further, we describe how DOD could collect additional data on additional aspects of projects that would enable DOD to get improved estimates of this ROI. The third section describes the data that are available on DOD spending on DR operations, and states how much DOD has been spending on these operations in the recent past.

In the fourth section, we present the results of two case studies estimating the ROI of two recent climate-related DRR projects that DOD conducted recently. These case studies demonstrate methods of how the data on DRR project costs and the cost of DR missions can be combined with data on the frequency of disasters in the country and the proportion that DOD has responded to in the past to estimate the ROI of the project. The ROI estimates from our case studies also provide some preliminary evidence on how often the ROI to DOD of DRR projects is greater than 1.0 (i.e., the expected benefit in terms of DOD being tasked with doing fewer or smaller DR missions exceeds the cost to DOD of doing the DRR project).

In the fifth section, we outline another method of estimating the ROI of climate-related DRR projects in general and the ROI of projects in specific categories. This method uses data on the estimated vulnerability of countries to the effects of climate change from the Notre Dame Global Adaptation Index (ND-GAIN index) combined with data on ROI-related outcomes, such as the amount of climate-related DR missions DOD performed in countries in the past and the number of deaths and dollars of property damage the countries experienced from climate-related disasters in the past. Doing DRR projects improves this index. If better values of the index are indeed associated with better outcomes, the size of these statistical associations along with data on the cost of improving the index and the cost of the outcomes can be used to estimate ROI. We also start applying this method in this fifth section, and report on some statistical associations we found between this index and these outcomes. Lastly, the conclusion section presents a summary of findings.

Literature review of prior efforts to assess values of DRR activities

We conducted a literature search looking for prior studies that estimated the ROI of DOD DRR projects, and of DRR activities conducted by civilian-sector entities and foreign militaries around the world. We also reviewed information about specific DRR projects in DOD's online databases for compiling and distributing information about these projects: the Overseas Humanitarian Assistance Shared Information System (OHASIS) database, which is an unclassified online database containing data on projects funded from FY 2011 through the present time [2]; and the Theater Security Cooperation Management Information System (TSCMIS) website, a SIPRNET database which collects additional project evaluation information about DRR projects along with other Theater Security Cooperation operations, activities, and actions in general [8].

We were unable to find any prior analysis that estimates the ROI of DRR activities done by US DOD, even though the US has been doing such activities for over 20 years [1] and US DOD's spending on DRR projects is approximately 5 percent of total global spending on DRR [2, 8].[1] DOD is supposed to complete both 30-day and 1-year After-Action Reports (AARs) evaluating how each completed DRR project appears to have gone as of 30 days and 1 year after the project was completed, respectively. We reviewed some of the AARs that have been posted on these websites, and did not find any estimates of ROI in them (although they often contain detailed information about whether other types of program objectives were met). Furthermore, as a 2012 GAO report on managing DOD's humanitarian and development assistance projects noted [1], post-project evaluations have often not been completed for many of these projects that have been completed. GAO found that "From fiscal years 2005 through 2009, DOD had not completed 90 percent of the required 1-year post-project evaluations for its OHDACA projects, and about half of the required 30-day evaluations for those projects, and thus lacks information to determine projects'

[1] Recent other research on DOD humanitarian assistance has also noted that "DoD's humanitarian activities have a longstanding, rich role in the theater commander's portfolio…. Yet, a comprehensive analysis of return on investment has not been carefully done by any organization within DoD [9]."

effects." In the current OHASIS database, for projects funded between FY 2011 and FY 2016 that have been completed as of the time of writing, we determined that 1.7 percent have both a 30-day and a 1-year post-project AAR completed for them, and another 60 percent have the 30-day but not the 1-year AAR completed.

Despite this lack of prior analysis on the ROI of DOD's DRR efforts, a large literature estimating the ROI of many civilian-sector projects by civilian government agencies and non-governmental organizations exists [6-7]. At least 68 studies have been written that each contain case studies estimating the ROI of one or more DRR projects or sets of projects. This literature does contain many results relevant to some arguably important criteria for managing DOD's DRR efforts, although it contains little or no information about other arguably important criteria.

On the one hand, this civilian-sector literature focuses almost exclusively on the benefits of the projects to the countries in which the projects are done, in terms of reduced numbers of deaths, persons left injured, homeless, or in need of emergency supplies by disasters, and reduced dollars of damage to property [6]. Potential benefits to foreign nations and non-governmental organizations (NGOs) in terms of their having to give the nation in which the DRR project is in fewer dollars of disaster relief aid (or, if not strictly having to give the aid, now being in a situation where they can decide not to with a clear conscience because the damage from future disasters is lower) was only measured in one study, and this study measured the savings to NGOs from countries other than the country in which the project was done, not militaries from other countries, such as US DOD, that sometimes conduct disaster relief operations in foreign nations [6].

Furthermore, because the literature is on projects done by civilian-sector agencies, it does not evaluate the ROI of types of DRR projects that are specific to militaries—such as US DOD training foreign militaries in how to better manage the logistics of airlifting supplies to disaster-struck areas and airlifting evacuees from such areas, or training foreign air forces in how to better conduct search-and-rescue missions for disaster victims [2, 6].

On the other hand, the civilian-sector literature does have some findings that pertain to criteria that may be important to DOD in making decisions about which and how many DRR projects to fund. Well over half of DRR projects that have been evaluated appear to have good ROI: fewer than 15 percent of the case studies of projects estimated that the projects cost more money than they were estimated to save, and of the projects that saved money, benefit-cost ratios are usually greater than two and often much greater. Because DOD actually conducts many DRR projects that are the same as or similar in nature to those that civilian-sector entities often do—such as flood prevention projects (see [2, 6] and the section below on categories of DRR projects that DOD does)—it can infer from the civilian-sector literature that many, quite possibly most, of its DRR projects do save the host nations in which the projects are done more money than they cost DOD. Thus, they likely have good ROI from the perspective of the world as a whole, whether or not they save DOD more money in disaster response operation costs than it costs DOD to undertake the DRR projects.

The civilian-sector literature indicates that it is not ideal to prioritize different types of DRR projects over others. Instead, it is better to look at the expected returns of specific individual projects, rather than simply choosing to do some types of projects instead of others.[2] The civilian-sector literature has found that within any given type of project (or at least those types for which the literature has estimated the individual-project-level-returns of multiple different projects), there are some projects with very high expected returns that are expected to save far more money than they cost, others with very low expected ROI expected to save far less money than they cost, and many in between [6]. So, just choosing to prioritize the types of projects that have higher returns on average (average across projects) than other types will not produce as high an ROI across the portfolio of funded projects as figuring out which specific individual projects have the highest expected individual-project-level returns, and funding those projects.[3] Shreve and Kelman, authors of the

[2] For instance, giving projects improving physical infrastructure for mitigating floods top priority, followed by giving projects improving physical infrastructure for mitigating droughts second-highest priority, followed by giving disaster mitigation training to foreign militaries third-highest priority, giving training to foreign medical service providers fourth-highest priority, and so forth.

[3] A simple numerical example may help illustrate this point. Suppose there are two types of projects that can be funded: projects of Type A have benefit-cost ratios of either 10 or 3 (e.g., some of these projects save $10 in disaster relief and response and recovery costs for every $1 spent on disaster risk reduction, and others save $3 for every $1 spend on disaster risk reduction), and projects of Type B have benefit-cost ratios of either 7 or 2. Further assuming that within Type A's, returns of 10 and 3 are equally likely, and within Type B, returns of 7 and 2 are equally likely, the average return of Type A projects is 6.5 (because (10+3)/2=6.5), and the average return of Type B projects is 4.5 (4.5=(7+2)/2). So, a decision to fund only Type A projects because they have higher returns on average than Type B projects, and then not looking at the expected individual-project-level returns of the potential Type A projects that get selected for funding (just picking Type A projects to fund at random rather than figuring out which ones have returns of 10 rather than 3), selects a portfolio of projects with an average return of 6.5. In contrast, if the decision-maker is able to estimate the expected returns of specific projects, and fund those with the highest expected individual-level-project returns first, they can fund a portfolio of projects with an expected return of 10 across the whole portfolio if there are more potential projects with an ROI of 10 than they have money to fund, or a portfolio of projects with an average return between 10 and 7 if there is more than enough money to fund every potential project with an ROI of 10 so that some projects with an ROI of 7 are also funded. In either case this is a higher expected return than the return of 6.5 from only funding Type A projects and selecting which Type A projects to fund at random. So, again, we recommend not prioritizing certain types of projects for funding ahead of other types whenever it is possible to estimate the expected returns of individual projects within each type and prioritize on that instead.

2014 literature review of civilian-sector disaster risk reduction ROI studies that is reference [6] of this study, make this same point and phrase it as follows: "As such, comparing locations, hazards, or scales might not yield results which are meaningful for decision-making. Instead, to determine financially whether or not a DRR measure or process should be implemented, calculations need to be made for that specific case study…." Reference [7] by the Overseas Development Institute (an NGO located in the United Kingdom) reviews global disaster risk reduction efforts and disaster losses (property damage, deaths, need for medical care, etc.) between 1991 and 2010, and argues redistributing currently available funding for DRR projects from some countries to others would cause the average funded DRR project to have higher ROI than before (or at least to provide better value when one considers the number of disaster-related deaths that are averted). They find that

- Funding for DRR is concentrated in relatively few, mostly middle-income countries, suggesting that potential projects with even better returns than many projects that were funded are available in other countries—namely, lower-income countries and countries that had received less investment.[4]

- Funding for DRR projects could be made more strongly correlated with country-level measures of mortality risk from natural disasters and country-level measures of the percentage of the population affected by drought, suggesting that the number of people who die in disasters and who are affected severely by drought each year could be reduced globally by redistributing funding for DRR projects from some countries to others; and

- The poorest countries, those with GDP per capita below $100 per year, receive less than 20 percent of total global funding for DRR projects, suggesting that value could be obtained from existing levels of global funding for DRR investment if more projects were funded in the poorest countries and fewer were funded in richer countries, the idea being that those in the poorer countries are actually more vulnerable and suffer a greater risk of injury or death and a larger percentage of what property they do have when disasters strike [7].

[4] The idea here is that there are only a finite number of potential projects with very high ROIs that can be done in each country. So it is easier to find potential projects to fund that have very high expected ROIs in countries where fewer DRR projects have been completed than in countries where many have been. Furthermore, higher-income countries are likely to have done more investment that mitigates the effects of disasters, even when the available, necessarily incomplete data on spending on DRR projects says that spending has been roughly the same in a set of countries.

Nonetheless we recommend that DOD decide which potential DRR projects to fund based on estimates of the ROI of individual projects whenever possible, because reference [6], which unlike [7] actually examines ROI estimates for individual projects, finds that, like with project type, within each country, there are some projects with very high expected returns, others with very low expected ROI, and many others at different points in the range between very high and very low returns [7]. In the absence of individual-project-level ROI estimates we contend that the country-level metrics measuring mortality risk from natural disasters and country-level measures of the percentage of the population affected by drought identified by the ODI in [7] would be helpful for DOD to use in prioritizing projects. These metrics are clearly related to disaster risk and directly measure risk of exposure to disasters. Prioritizing by countries' income (GPD per capita) is less clearly related to the returns from investment, though. For instance, if DOD is concerned about which countries are more likely to experience violent unrest and conflict after a natural disaster, this may actually have more to do with the amount of political rights in a country and other characteristics besides GPD per capita: [10] finds that the amount of political rights in a country, linguistic fractionalization, and some measures of climate are statistically associated with how much terrorist activity occurs in a country, but that GDP per capita is not.

Although there are lessons to be learned from the civilian literature, we must caution against taking too much from it, because our ROI metric is fundamentally different: measuring whether military forces would be called on to respond to a disaster at all, or with a significantly smaller level of effort. ROI to DOD will be high if the DRR efforts either mitigate the damage to an amount manageable by the foreign government or NGOs, or enhance the capabilities of the foreign military forces to undertake the required response tasks in lieu of DOD doing them. As a first step to showing how the ROI to DOD can be estimated, in the next section we present data on the cost to DOD of doing different categories of DRR projects. This cost is the denominator in the benefit-cost ratio that measures the ROI of the projects; the numerator is the reduction in DOD spending on disaster response projects.

Categories of DOD DRR projects and costs

Next, we characterize the types of Theater Security Cooperation (TSC) activities geographic combatant commanders (GCCs) conduct in foreign countries. We identify which of these activities help partner nations build the capacity and capability to mitigate the damages from climate- and climate-change-related natural disasters, and which do not (i.e., which are climate-related DRR projects and which are not). We divide the projects into several sub-categories, which will allow us to estimate the costs to GCCs of conducting different types of climate-related DRR activities. The sub-categories also will help address the issue of whether it makes sense to prioritize investment in some types of DRR projects over other types.

In relation to the civilian-sector literature discussed in the previous section, we found that many of DOD's DRR activities are similar to the DRR projects conducted by civilian-sector entities. Thus, the project categorization scheme for DOD DRR projects we use below is similar to project categorization schemes used in the civilian sector literature. However, DOD does conduct some types of projects—for instance, disaster mitigation and preparation training projects for foreign militaries—that the civilian sector does not. Nonetheless, when DOD conducts projects that are the same type as or similar to what civilian-sector agencies do, we assert that it is reasonable to make some inferences about what the benefits to the host nation (HN)—the foreign country in which the project is done—will be. DOD can use the results of the civilian-sector literature to evaluate the returns of projects of that type.

As described in [4], "Theater Security Cooperation (TSC) refers to activities conducted with allies and friends that are intended to (1) build relationships that promote U.S. interests, (2) enhance allied and friendly capabilities for self-defense and coalition operations and (3) provide U.S. forces with peacetime and contingency access [8]. Typical types of TSC events include conferences and educational presentations, high–level leadership visits, counterdrug activities, humanitarian assistance projects, and bilateral and multilateral military exercises". DOD's TSC activities are described in detail in other sources such as GAO reports [1], other analysis of the programs [4] and DOD websites [11]. Detailed information on the humanitarian assistance TSC efforts, including DRR projects, is contained in a database called the Overseas Humanitarian Assistance Shared Information System (OHASIS). OHASIS contains information and data for each DOD humanitarian assistance project funded between FY 2011 and FY 2016, as well as information and data for project proposals that were developed and submitted in those years but not selected for funding. OHASIS contains summary information in spreadsheet form about each project and project proposal, as well as detailed descriptions and other documents about each one.

The OHASIS database contains three variables that categorize the projects and project proposals in the database into different categories: Project Type, Sector, and Sub-Sector. The Sub-Sector category can be used to determine which projects are climate-related DRR activities. The Sub-Sector variable can also be used to further break the climate-related DRR activities down into different subcategories for analysis. Below we present tables showing the different subcategory values the Sub-Sector variable takes, which of these subcategories are climate-related DRR activities, the number of projects that were completed or funded between FY 2011 and FY 2016 within each subcategory, and the cost estimate in the databases for these projects, aggregated across projects to give an average cost per project within the subcategory.

Table 1. Sub-sectors of DOD TSC projects that are DRR projects or closely related to climate issues

	# of projects between FY11 and FY16	total cost across projects	avg cost per project
Cachements	5	$710,000	$142,000
Cistern	6	$877,447	$146,241
Disaster mitigatation and preparation-related medical training	1	$50,000	$50,000
Disaster mitigatation and preparation-related site assessment	11	$3,769,000	$342,636
Disaster mitigatation and preparation-related site visit	3	$146,800	$48,933
Disaster mitigatation and preparation-related subject matter expert exchange	89	$15,960,685	$179,334
Disaster mitigation and preparation equipment	46	$1,980,403	$43,052
Disaster mitigation training	44	$9,139,227	$207,710
Disaster preperation training	70	$17,624,327	$251,776
Disaster shelter	23	$2,145,005	$93,261
Disaster shelter/community center	14	$1,516,504	$108,322
Disaster shelter/school	17	$4,298,640	$252,861
Disaster warehouse	25	$5,710,289	$228,412
Drainage/Sewage	4	$795,550	$198,888
Emergency operating center	45	$21,007,009	$466,822
Fire prevention/control	9	$2,614,221	$290,469
Fire station	12	$3,842,403	$320,200
Flood prevention/control	209	$76,408,000	$365,589
Wells	51	$8,895,165	$174,415

Note: we have recorded our reasons for defining these projects as directly or closely related to climate in tables below

Table 2. Sub-sectors of DOD TSC projects that are indirectly related to climate DRR

	# of projects between FY11 and FY16	total cost across projects	avg cost per project
Bridges	8	$4,029,585	$503,698
Clinic and Hospital	142	$42,276,295	$297,720
Community center	44	$6,161,377	$140,031
Education Training in basic infrastructure	1	$480,000	$480,000
Equipment project in Health Support Sector	147	$10,611,334	$72,186
Global Health	31	$2,093,201	$67,523
Health Support Subject Matter Expert Exchange	50	$7,276,828	$145,537
Health training	18	$1,082,970	$60,165
HIV/AIDS	37	$5,920,501	$160,014
Infant/child health	16	$1,223,000	$76,438
Latrines	18	$2,619,200	$145,511
Malaria	5	$81,500	$16,300
Medical training--general medical projects in the Health Support sector	131	$6,293,792	$48,044
Medical--general medical projects in the Health Support sector	237	$13,912,394	$58,702
Other communicable diseases (specify)	10	$2,276,771	$227,677
Roads	6	$1,579,928	$263,321
Site Visit related to Basic Infrastructure	10	$708,500	$70,850
Subject Matter Expert Exchange related to Basic Infrastructure	60	$7,648,075	$127,468
Veterinary	17	$444,925	$26,172
Women's health	5	$917,830	$183,566

Note: we have recorded our reasons for defining these projects as indirectly related to climate in tables below

Table 3. Sub-sectors of DOD TSC projects that are not climate-related DRR

	# of projects between FY11 and FY16	total cost across projects	avg cost per project
Dental project in the Health Support sector	11	$382,000	$34,727
Disability/Disabled project in the Health Support	17	$879,313	$51,724
Dorm/student housing	2	$30,000	$15,000
Education Support Sector	542	$93,853,153	$173,161
Elderly project in Health Support Sector	20	$5,916,683	$295,834
Group home	31	$2,590,443	$83,563
Maternal health	37	$7,468,655	$201,856
Mine action	2	$693,000	$346,500

Note: we have recorded our reasons for defining these projects as unrelated to climate in tables below

By "directly or closely related to climate," we mean that the DRR project is specifically intended to reduce the potential damages from climate disasters such as floods, storms, droughts, intense heat waves, or is a general disaster risk reduction project, such as an Emergency Operations Center, that can be used to respond to all types of disasters, both climate-related and those not related to climate (such as earthquakes). By indirectly related to climate, we mean that the project is primarily intended to serve purposes other than climate-related risk reduction, but it can at least sometimes be used to mitigate the damages from climate disasters, at least somewhat. For instance, roads and bridges are primarily used for transportation purposes when there is no disaster occurring, but can be used to help flee a disaster or bring in supplies afterwards. Projects that are unrelated to climate DRR are those that we consider to provide no means of reducing the damages from climate disasters.

Our reasons for defining each of these sub-sectors projects as being either directly, indirectly, or unrelated to climate disaster risk reduction are given in the following tables:

Table 4. Reasons for defining some sub-sectors of projects as directly related to climate DRR

Sub-sector:	Reason:
Cachements	Cachements, also known as catchments, catch water, so, these projects help with droughts and flooding
Cistern	A cistern is a reservoir, tank, or container for storing or holding water or other liquid--so , cistern projects are directly related to droughts and storms
Disaster mitigatation and preparation-related medical training	For the sub-sectors whose titles begin with "Disaster", we have found that it is best to assume that they are directly related to climate DRR. This is because any project that addresses disasters in general is useable in climate-related disasters, and because most disasters are climate-related--earthquakes and tsunamis are the only major exceptions.
Disaster mitigatation and preparation-related site assessment	
Disaster mitigatation and preparation-related site visit	
Disaster mitigatation and preparation-related subject matter expert exchange	
Disaster mitigation and preparation equipment	
Disaster mitigation training	
Disaster prep training	
Disaster shelter	
Disaster shelter/community center	
Disaster shelter/school	
Disaster warehouse	
Drainage/Sewage	This sub-sector is related to floods, droughts, and preventing storm runoff from spreading disease, etc.
Emergency operating center	These centers can be used in a climate disaster
Fire prevention/control	While most fires aren't climate related, because forest and brush fires often are, and storms and heat waves can sometimes help cause fires (storms can knock over electric wires or hit gas pipes, which can start a fire), we consider this sub-sector to be directly related to climate
Fire station	Again, most fires aren't climate related, but firefighters and fire trucks often participate in the response to disasters--they do not deal solely with fires
Flood prevention/control	Floods are a climate-related disaster
Wells	Wells help mitigate the effects of flooding and drought

Table 5. Reasons for defining some sub-sectors of projects as indirectly related to climate DRR (table continues on next page)

Sub-sector:	Reason:
Bridges	Studier bridges can better withstand disasters; bridges in place after disasters can facilitate transporting supplies; however, the main point of bridges is to use them when there's no disaster
Clinic and hospital	Very useful for treating people hurt by disasters, but the main point is to provide care during non-disaster times. Still, disasters cause injuries and illness, which is what hospitals treat
Community center	Some community shelters can be strong enough to use as a shelter after a disaster. However, because there is a separate sub-sector called Disaster Shelter/Community Center, we consider these projects to be only indirectly related to climate disasters
Education training in basic infrastructure	Most basic infrastructure helps make the country more resilient to disasters
Equipment for basic infrastructure	Most basic infrastructure helps make the country more resilient to disasters
Equipment project in health support sector	Very useful for treating people hurt by disasters, even if the main point is to provide care during non-disaster times.
Fire prevention/control	Droughts, storms, etc. sometimes carry fire risks
Global health	If people are healtier, they can better cope with droughts and food shortages, and can better seek shelter from floods, storms, other disasters
Health support subject matter expert exchange	Very useful for treating people hurt by disasters, even if the main point is to provide care during non-disaster times.
Health training	Better trained health providers can provide better assistance in a disaster
HIV/AIDS	People who are less ill from HIV and AIDs are more resilient to climate disasters--they can better grow food, find water, etc.
Infant/child health	Very useful for treating people hurt by disasters, even if the main point is to provide care during non-disaster times
Latrines	Having better latrines could help stop the spread of disease after disasters; further as we discuss for the malaria and disease sub-sectors, some researchers argue that there will probably be greater spread of disease as the climate changes

Sub-sector:	Reason:
Malaria	The spread of malaria is a disaster in and of itself, so projects to address malaria are disaster mitigation--further, climate change could increase the spread and risk of infectious diseases including malaria--a Google search pulls up many articles on that topic, for instance http://science.time.com/2013/08/02/infectious-disease-could-be-more-common-in-a-warmer-world-especially-for-plants-and-animals/ and http://www.epa.gov/climatechange/impacts-adaptation/health.html#impactsdiseasesadaptation/health.html#impactsdiseases
Medical training--general medical projects in the health support sector	Very useful for treating people hurt by disasters, even if the main point is to provide care during non-disaster times.
Medical--general medical projects in the health support sector	Very useful for treating people hurt by disasters, even if the main point is to provide care during non-disaster times.
Other communicable diseases	The spread of diseases is a disaster in and of itself, so projects to address diseases are disaster mitigation--further, climate change could increase the spread and risk of infectious diseases--a Google search pulls up many articles on that topic, for instance http://science.time.com/2013/08/02/infectious-disease-could-be-more-common-in-a-warmer-world-especially-for-plants-and-animals/ and http://www.epa.gov/climatechange/impacts-adaptation/health.html#impactsdiseasesadaptation/health.html#impactsdiseases
Roads	Like the bridge category above--sturdier roads can better withstand disasters, etc.
Site visit related to basic infrastructure	Most basic infrastructure helps make the country more resilient to disasters
Subject matter expert exchange related to basic infrastructure	Most basic infrastructure helps make the country more resilient to disasters
Veterinary	This can help animals--which in these countries are mainly for agriculture, not pets--better recover from injuries suffered in storms and floods, and better deal with food shortages and drought-related injuries. So, this sub-sector is indirectly related to climate disasters.
Women's health	Health projects in general help people recover from injuries and illness from disasters, even if the main point is to provide care during non-disaster times.

Table 6. Reasons for defining some sub-sectors of projects as unrelated to climate DRR

Sub-sector:	Reason:
Dental project in the health support sector	Dental health has little relation to being able to cope with disasters
Disability/disabled project in the health support sector	These projects presumably are intended to assist the disabled with their day-to-day lives, not anything specific to disasters
Dorm/student housing	Not specifically intended as a disaster shelter
Education support sector--all of the sub-sectors within this sector	While education increases earnings and improves behavior in all areas of life, if the earnings aren't spent on disaster mitigation projects, education isn't relevant to this task. Similarly we believe that it would be too speculative to presume that there is a large effect of having better emotional intelligence and non-cognitive skills on being able to better cope with disaster
Elderly project in health support sector	Similarly with projects for the Disabled--a clinic/hospital for all types of patients is probably better at helping the elderly in a disaster than an elderly-specific health sector project
Group home	Not specifically intended as a disaster shelter
Maternal health	Making sure expectant mothers are healthy has little connection to preparing for disasters--you want them to be healthy regardless of the likelihood of disaster--and you can have healthy mothers and still not be well prepared for disasters
Mine action	Land mine risks are unrelated to climate disasters

Note that Tables 1 through 3 provide information about the cost per project for the projects in the OHASIS database. This database is set up to display information about all of the projects in it in spreadsheet form, in a spreadsheet that contains a variable for the estimated cost of the project.[5] Because these data have dollar spending on projects, they could be used in statistical analysis measuring the associations at the country or region level between dollars of spending on different subcategories of DRR projects in the country or region and disaster-related outcomes in the country or region. These would be outcomes such how much money DOD spends on disaster response operations after disasters occur in the countries or regions (a goal of DRR projects is to reduce DR spending), and how many deaths and dollars of damage to property are caused by disasters in different countries. Because different dollar amounts are spent on different subcategories of DRR projects in different countries, one can do statistical analysis measuring whether these differences in spending are associated with better outcomes.

Measuring these statistical associations is an approach to estimating the ROI of the DRR projects—it measures how much better outcomes are when different amounts are spent on DRR projects. We do not take this approach to measuring the ROI of DOD DRR spending this way in this paper because the scope and size of the project

[5] The spreadsheet data also contain a variable for final actual cost, but since we wanted to include data on funded but not yet completed projects in the tables, we used the estimated cost variable.

did not allow us to collect sufficient data on the many other factors besides DOD DRR spending that affect these outcomes (e.g., civilian-sector spending on DRR projects, rate at which climate disasters occur in the country to begin with and their size in purely physical terms, etc.). Without controlling for these factors, we contend that statistical analysis would run into a "correlation, not causal" problem in which the associations between the DOD DRR spending and DR outcomes are unlikely to be causal estimates of the effect of DRR spending on outcomes.

However, we note that analysis of the ROI of DOD DRR projects that uses this method would be greatly facilitated if the OHASIS spreadsheet data were able provide summary measures of project scale, such as number of persons served and measures of the extent to which they are protected by the project.[6] With data on project scale, one could do statistical analysis (specifically, regression analysis) measuring statistical associations between the measures of scale and outcomes, rather than only measuring the statistical associations between past dollar spending on projects and outcomes. With measures of the relationship between project scale and outcomes, one can better forecast the expected ROI of specific proposed individual projects. That is because one can forecast the proposed project's expected benefits based on its scale, rather than only its cost. If the project has a large scale relative to its cost, it will have an ROI per dollar that is higher than the average ROI per dollar of projects of that type that were funded in the past.

ROI depends on the size of the benefits, which are proportional to the number of people served, and how they are served—for instance, the more people are potentially affected by disaster, the greater the response would need to be, and the greater the savings from doing the project). However, with only information on the average relationship between dollar spending on DRR projects and outcomes in the past, and no information on the average relationship between scale and outcomes, one would not be able to determine which projects have large scale relative to their cost—and so, one would not be able to identify, going forward, which project proposals have high benefits relative to other proposed projects and relative to the average project funded in the past because they have large scales.

[6] Other information in OHASIS provides some measures of scale for many projects, although the particular measures used are up to the discretion of the project team—there are no standard sets of measures of scale for specific types of projects. While this information is not coded up numerically in the summary spreadsheets—some of it is contained along with other information in long text variables in the spreadsheet, other information is contained in longer project descriptions for each individual project that are separate from the spreadsheet data—it can be used in case studies estimating the ROI of individual specific projects. Later in the study we use some of this information on scale in case studies of a few specific projects.

The two other variables that categorize projects in OHASIS—Project Type and Sector—are worth describing further. Project Type gives information on what program funded the project, or under what program DOD is seeking to fund a proposed project [2]. The programs are the OHDACA (Overseas Humanitarian, Disaster Assistance, and Civic Aid) program funded by the Defense Security Cooperation Agency (DSCA), which funds projects of the Humanitarian Assistance (HA), Excess Property and Mine Action Project Types; the Humanitarian Assistance (HCA) program funded by the Joint Staff; and the Asia Pacific Regional Initiative funded by Pacific Command (PACOM). The two main categories of projects in terms of volume of funding are OHDACA HA projects and HCA projects. Project Type does not determine Project Sub Sector (or Sector): projects within most Sub-Sectors can be funded as different project Types. For instance, different projects in the Flood Prevention and Control Sub-Sector have been funded as OHDACA HA, OHDACA Excess Property, HCA, and Asia Pacific Regional Initiative projects. The purposes of and rationales behind the OHDACA and HCA programs, as explained in [1, 8], are:

- Improving DOD visibility, access, and influence while building and/or reinforcing security and stability in a host nation or region;
- Providing disaster mitigation training and/or bolstering host nation capacity to avert humanitarian crises and response to disasters; and
- Generating collaborative relationships with a host nation's civil society as well as positive public relations and goodwill toward DOD.

In addition to advancing U.S. defense interests, DOD's policy guidance states that humanitarian assistance efforts should address the humanitarian needs of the targeted population. Furthermore, the assistance must fulfill unit training requirements that incidentally create humanitarian benefit to the local populace.

The Project Sectors, as categorized by the OHASIS database's Project Sector variable, are: Basic Infrastructure, Disaster Mitigation and Preparation, Education Support, Health Support, Medical/Dental, and Mine Action. While projects in a certain Sub-Sector can be funded from different sources and therefore be of different Types, with a handful of exceptions, if a project is in a certain Sub-Sector, it follows that it is in a specific Sector and not any other [2]. For instance, Bridges and Roads (both sub-sectors) are Basic Infrastructure projects. However, a few Sub-Sectors have projects that sometimes get categorized as belonging to one Sector and sometimes to another—for example, Clinic/Hospital sometimes is in the Basic Infrastructure Sector and other times is in the Health Support Sector.

DOD spending on disaster relief: spending levels and data sources

DOD's DRR projects may reduce its tasking to perform disaster response operations in foreign countries. Because DR operations cost DOD money to execute, DRR projects can save DOD money as a result—if not on net (i.e., the benefit/cost ratio being greater than 1.0), then at least lessening the need for DR operations. In this section, we describe DOD's DR operations, state where sources of data on what tasks are done in the DR missions and how much they cost are, and summarize some of the information available in these cost data. In the next section, we use some of these cost data in case studies estimating the return of specific DRR projects that DOD has completed. In this section, we also describe how future work estimating the ROI of DOD DRR projects could make use of other sources of cost data on DR missions.

After disasters in foreign countries, DOD can perform DR missions if there is a formal request from the host nations [4]. The U.S. State Department, not DOD, is actually the department that manages the overall U.S. disaster response effort in the host nations. The missions are coordinated by the USAID Office of Foreign Disaster Assistance (OFDA), so the U.S. military always operates in support of another U.S. government agency. The missions that DOD does as part of disaster response operations tend to focus on transporting and donating relief aid, especially by air and sealift support; medical evacuation of host nation citizens; search and rescue missions; and assisting persons displaced by the disaster by providing supplies and services [5, 12].

As for HA efforts (many of which are DRR projects), DOD funds its DR efforts though the OHDACA appropriation [5]. Within the OHDACA appropriation, DR efforts are funded under the "Foreign Disaster Relief Initiatives" program. Information on how much DOD spends on these Foreign Disaster Relief Initiatives every year, in aggregate across all DR operations done that year, can be found in the annual budget estimates. Table 7 presents data on total Foreign Disaster Relief spending from these annual budget estimates for 2008-2014, along with total OHDACA HA spending and HCA program funding for comparison.

Table 7. Total DOD spending on disaster relief, humanitarian assistance, and humanitarian civic assistance, FY 2008 – FY 2014 (in thousands of dollars)

Year of spending:	2008	2009	2010	2011	2012	2013	2014	TOTAL
Total DOD Foreign Disaster Relief Initiative spending:	$69,801	$7,743	$500,993	$230,079	$4,766	$541	$48,100	$862,023
OHDACA HA program spending:	$57,871	$82,825	$81,179	$104,623	$108,801	$105,017	$108,700	$649,016
HCA program spending:	$15,000	$14,000	$15,000	(no data available)		$8,487	$7,428	$59,915

Notes: data sources are references [1], [2], and [5]. These references do not provide data for HCA spending in 2011 and 2012, however. Data are in thousands of dollars.

Note from Table 7 that spending on foreign DR varies greatly from year to year—from a low of only $541,000 in 2013, to a high of $500,993,000 in 2010. That is because the number of disasters varies from year to year, and because in some years, a very large disaster occurs that requires a very large DR operation from DOD. Examples include the Haiti Earthquake (2010), Pakistan Flooding (2010), Japan Earthquake (2011), and Philippines Typhoon (FY 2014).

In addition to these data on total spending each year across all DR missions, we have found that data exist on spending on individual missions that occurred in the past (at least for notably large high-profile missions). We have also found that data and tools also exist for estimating what costs DOD incurred on past missions and what would need to be spent on hypothetical future missions of different sizes and tasking.

For large prominent DR missions, DOD releases information on what the total cost of the mission was, which units were involved, and what tasks they did: e.g., how many sorties and flying hours DOD aircraft spent delivering supplies and transporting evacuees. Reference [13] analyzes incremental cost data from the responses to the 2004 Indian Ocean tsunami, the 2010 Haiti earthquake and the 2010 Pakistan floods, (analyzing costs for) both their timing and the associated functional service provided"; this demonstrates that DOD collects such data, and provides references on where to find it for those operations. Reference [14] provides data on Operation Damayan in which DOD provided DR in response to Typhoon Haiyan in the Philippines. It states that this operation cost DOD $31.7 million, that according to PACOM the U.S. military flew more than 1,300 relief sorties and delivered more than 2,495 tons of supplies in the mission, and that at the peak of the operation, more than 13,400 U.S. military personnel from all the services, 66 aircraft and 12 Navy ships participated in the operation.

As stated above, transporting and donating relief aid, medical evacuation of host nation citizens, and search and rescue missions are the primary tasks DOD does in DR operations. The primary cost of doing these is operations and maintenance (O&M) costs for the aircraft, ships, vehicles, and equipment involved in doing the missions.[7] This is because using them incurs fuel costs and creates a need for more maintenance due to the extra use. DOD publishes standard O&M cost factors for using aircraft, ships, vehicles, and equipment, such as the flight hour costs for aircraft [15] and per-mile O&M costs for vehicles [16]. These cost factors, along with a sense of the number of flight hours from different types of aircraft that will be needed for the mission, the number of miles different vehicles will need to travel for the mission, etc., can be used to get a rough but still at least somewhat reasonable estimate of the cost of a prospective DR mission.

A more accurate estimate of the cost of a prospective DR mission (or of one that DOD did in the past) that incorporates a comprehensive set of cost elements and cost considerations, not just O&M for aircraft, ships, vehicles, and equipment—e.g., sea duty pay for Sailors who spend more time than planned at sea because they are tasked with doing DR missions, and determining whether they indeed spent more time at sea because of the additional mission or simply spent less time on other missions and the same amount of time at sea)—can be obtained from the Contingency Operation Support Tool (COST) model developed for the Under Secretary of Defense (Comptroller) by the Institute for Defense Analysis (IDA). IDA's COST model is the standard Overseas Contingency Operations cost estimation tool mandated for use by all DOD components and agencies to "estimate the incremental cost of operational deployments for all contingency operations", including DR missions [17]. A promising avenue for future research on the ROI of DRR projects would be to use the COST model to estimate costs of DR missions, to better estimate the expected savings to DOD from the DRR projects. Again, the IDA COST model is a comprehensive, standard, commonly used model, and indeed DOD's Financial Management Regulation mandates that components and defense agencies use it to estimate the cost of contingency operations.

[7] New aircraft, ships, and vehicles are not procured to do the missions, so procurement of equipment is an issue only to the extent that aircraft, ships, and vehicles reach the ends of their service lives and need to be replaced as a result of participating in DR missions. Further DOD personnel conducting the missions are personnel that are already in the force. They are not newly hired or retained specifically to do DR missions. So, the amount of base personnel pay and benefits is not affected by doing DR missions, because doing them does not affect end strength [4].

Case studies on ROI of individual DRR projects: methods and examples

In this section we present case studies estimating the ROI of two specific sets of climate-related DRR projects that DOD has conducted recently. These case studies demonstrate methods of how one can take data on DRR project costs and the cost of DR missions, combine these with data on the frequency of disasters in the country and the proportion that DOD is likely to respond to (based on how many they responded to in the past), and use it to estimate the ROI of the project. The estimation technique used in the case studies is a before-and-after comparison of the estimated need for DOD to do DR missions in the area served by the project both before it is done (or equivalently, without doing the project), and after it is done (or, with deciding to do the project). This is the estimation technique used in most of the literature evaluating the ROI of civilian-sector projects [6]. The ROI estimates from the case studies also provide some preliminary evidence on how often the ROI to DOD of DRR projects is greater than 1.0. These projects have a promising benefit-cost ratio because the expected benefit in terms of DOD being tasked with doing fewer or smaller DR missions exceeds the cost to DOD of doing the DRR project. We admit that his evidence is preliminary because more case studies would need to be done to generate a precise estimate of how often the projects and proposed projects would have benefit-cost ratios greater than 1.0.

To select which projects to evaluate in our case studies from amongst the hundreds of projects DOD has done, we examined the details in the OHASIS database [2] about different projects that were in the Disaster Mitigation and Preparation and Basic Infrastructure sectors; that also had been completed as of time of writing and had 30-day After Action Reports (AARs) completed for them as well; and that were not “Minimal Cost” (cost less than $15,000) projects. There are 151 such projects in the OHASIS data. Reading through the descriptions of all of them, we found that about 25 percent of them were both related to climate-disasters and also appeared to have enough information about the project in OHASIS that its likely effects and ROI could be estimated. We decided to focus on two sets of these projects in this study, sets that we thought were good for case studies because (1) DOD also does many other projects of the same or similar type, and (2) the assumptions needed to make to estimate ROI were relatively uncontroversial. However, there are other projects in the OHASIS data—including projects in the Health Support and Medical/Dental sectors, and projects that are not complete but are described in sufficient detail that their

ROIs can be estimated—that we maintain would make good case studies to explore in future research on the ROI of DOD DRR projects.

The first set of projects we examine provide training to the Philippines Air Force in the logistics of conducting air mobility operations, with an emphasis on airlift for humanitarian assistance and disaster relief operations. These projects have project numbers and titles RP-APR-2014-00022999: "AED Phase 1: Logistics, Maintenance and Ops Training Development" and RP-APR-2014-00023173: "AED Phase 2A: Foundations of Logistics Mission Support" in the OHASIS database.

The second set of projects built new roads to remote villages in the Philippines,[8] and also repaired roads serving such villages that had become unusable. The rationales for the roads projects, as stated in OHASIS in the executive summaries and descriptions of the outputs the projects achieved, mention that the projects were meant to improve access to and from the village's areas in the event of emergencies. For instance, the output descriptions of three of the projects say that the roads provide better for transportation of good and people in times of emergency; that the route provided the populace immediate egress/ingress during disaster mitigation; and that the road gives emergency responders immediate access to the area. The roads also provide farm to market route for the local populace. The roads projects are those with the following project numbers and titles in the OHASIS database: RP-HA-2012-00020150: "Amaloy Road", RP-HA-2012-00020318: "Route Ashley-Bella Road", RP-HA-2012-00020436: "Guinanta Road", RP-HA-2012-00020324: "Poona Piagapo Road", RP-HA-2012-00020435: "Marogong Road", and RP-HA-2012-00020760: "Route Lisa".

Projects training the Philippines Air Force in how to better conduct air mobility operations

These projects are an interrelated set of projects—different phases of an overarching project plan called the Air Enterprise Development effort—that aim to develop an organic air mobility system within the Philippines Air Force, a system that contains adequate logistics and operations and maintenance support and can participate in peacekeeping, humanitarian assistance, disaster relief and U.S.-led coalition operations in the Philippines and nearby countries. The projects are focused on providing training to the Philippines Air Force on how to conduct air mobility

[8] An advantage of doing two case studies on projects that are all in the same country (here, the Philippines) is that it allows us to investigate whether there can be projects in the same country that have very different ROIs.

operations. Other project tasks include planning for the training program—planning that consisted of engagement with key leaders, site surveys, subject matter expert exchanges, and drawing lessons from the recent large disaster relief operation in the Philippines that the U.S. and many other nations participated in (namely, Operation Damayan in response to Typhoon Haiyan in November 2013) [2].

Phases 1, 2A, and 2B of this project have cost $75,000, $80,000, and $75,000 respectively. DOD also plans to conduct a Phase 3 and Phase 4 as part of this project; Phases 1 and 2 alone will not complete the entire training process that is planned. We assume that Phases 3 and 4 will have parts 3A, 3B, 4A, and 4B, and that these will also cost about $75,000 each, for a total of $530,000 across the seven parts of the project.

Will this project save more money in reduced tasking for DOD to perform DR operations in the Philippines than it costs, so that it has positive ROI? To estimate this, we examined the frequency of disasters in the Philippines, the frequency with which DOD has done DR operations to them in the past that involve air lift, some information on the cost of these operations, and the number of aircraft of different types in the Philippines Air Force that are available to participate in DR operations. From this, we can get a sense of the likelihood that these DRR projects training the Philippines Air Force in Air Mobility will be able to generate enough extra capability in the Philippines Air Force that DOD saves enough money to recoup its project investment. If there is enough extra capability in the Philippines Air Force that this capability can take the place of U.S. Air Force and Navy aircraft capability, allowing DOD to do fewer and/or smaller DR missions, DOD can recoup this cost from being able to decide they need to do $530,000 worth of fewer air lift operations in the Philippines after the projects are finished.

Data on the frequency and impact (number of deaths, injuries, and dollars of property damage caused) by disasters in different countries around the world is available from a database called EM-DAT: The CRED/OFDA International Disaster Database published by the Centre for Research on the Epidemiology of Disasters (CRED) at the Université Catholique de Louvain in Brussels [18]. Table 8 below presents data on the frequency and impact of disasters in the Philippines over the years 1995 through 2014. We include non-climate-related disasters in the table because this project seeks to improve the ability of the Philippines Air Force to respond to all types of disasters, not just climate-related ones. However, the table shows that climate-related disasters, in particular floods and tropical cyclones, are the most common, highest-impact disasters in the Philippines.

Table 8. Frequency and Impact of disasters in the Philippines, 1995-2014

Disaster Type:	Average annual number of disaster occurrences	Average of annual deaths caused by disasters of this type	Average of annual number of people affected by disasters of this type	Average of annual number of people injured by disasters of this type	Average of annual number of people made homeless by disasters of this type	Average annual US dollars of property damage caused by this type of disaster
Air	1.25	71	0	5	0	$825,000
Ash fall	1.25	0	38,095	0	313	$599,250
Avalanche	1.00	6	1,200	0	0	$0
Bacterial disease	1.25	22	1,022	50	0	$0
Chemical spill	1.00	0	3,000	0	0	$0
Coastal flood	2.00	20	22,347	20	1,750	$840,000
Collapse	1.00	24	0	0	0	$0
Convective storm	1.00	4	0	2	2,300	$2,500
Drought	1.00	3	866,667	0	0	$151,000
Explosion	1.00	5	0	144	1,000	$0
Fire	1.57	36	3,571	15	5,850	$368,500
Flash flood	2.29	64	439,061	10	440	$71,833,143
Forest fire	1.00	2	300	0	0	$0
Ground movement	1.29	52	521,170	178	1	$9,600,143
Landslide	1.64	154	21,649	18	3	$843,727
Oil spill	1.00	0	17,000	0	0	$0
Other	1.33	34	0	353	0	$0
Rail	1.00	7	0	173	0	$0
Riverine flood	3.20	45	958,271	22	5,717	$158,951,400
Road	1.40	37	0	14	0	$0
Subsidence	1.00	287	2,800	38	0	$0
Tropical cyclone	6.24	985	4,931,674	2,396	20,203	$743,293,619
Viral disease	1.00	168	3,275	20,657	0	$0
Water	1.75	133	189	6	0	$0
Grand Total	37.45	2,157	7,831,292	24,100	37,577	$987,308,282

Source: EMDAT Database [18]

Notes: people "affected" by disaster are "people requiring immediate assistance during a period of emergency, i.e. requiring basic survival needs such as food, water, shelter, sanitation and immediate medical assistance." [18]

This data gives a sense of how many disasters occur in the Philippines that the U.S. military could assist with. There are very many of them—an average of 37.45 per year, causing 2,157 deaths, affecting nearly 8,000,000 people, and causing nearly $1 billion in property damage a year. But of these, how many are large enough that the Philippine government would ask US DOD for assistance, and DOD would then decide to provide assistance? We can get a sense of this from the historical frequency at which DOD has performed disaster relief operations in the Philippines in the past.

A CNA database of information on named U.S. military contingency operations from 1970-2003 [12] identifies which operations are DR operations, which country they were in, what type of disaster was being responded to (e.g., typhoon or earthquake), dates of the operations (which also states how many days they lasted), what units were involved, and, when it's available, some information about the work performed in the operation, such as whether relief supplies were provided, how many sorties were flown by DOD aircraft, and how many persons were evacuated by DOD. Table 9 provides information from this database for DR operations DOD has performed in the Philippines. We include non-climate-related disasters in this table because this training project aims to enable the Philippines Air Force to better respond to all disasters, climate-related and otherwise.

Table 9. U.S. DOD DR operations in the Philippines, 1970-2003

Mission Name	Mission Type	Event	Country	Event Date	End Date	Duration (days)	Navy units involved	Marine Corps units	Air Force units	Army units	notes
Philippine earthquake	Disaster Relief	earthquake	Philippines	16-Jul-90	30-Jul-90	15	Medical Contingency team	MAGTF 4-90, 13 MEU, 200+ troops	5 C-130, 2 C-141, 500 sorties	N	MC involved; MC: assisted in rescue ops
Pines Hotel Fire	Disaster Relief	fire (building)	Philippines	23-Oct-84	24-Oct-84	2	N	N	1 C-130, 1 H-3	N	58 evac; many Americans in the hotel
Operation Saklolo	Disaster Relief	flood	Philippines	21-Jul-72	15-Aug-72	26	Y	HMM-165	C-130, H-3, H-43	N	AF: flood relief in Luzon, Army, Navy, MC involved; MC: 2000 evac
Phillippine floods	Disaster Relief	flood	Philippines	1-Oct-73	1-Oct-73	1	N	N	1 C-130	N	relief supplies
Philippines Flood Relief	Disaster relief	flood	Philippines	18-Aug-74	24-Aug-74	6	Helos	31 MAU	N	N	MC: helos assisted
Philippine flooding	Disaster Relief	flood	Philippines	03-Sep-90	18-Sep-90	16	N	MAGTF 4-90, 94 troops	N	N	transport supplies, 453 evac
Typhoon Georgia	Disaster Relief	typhoon	Philippines	14-Sep-70	23-Sep-70	10	N	3 MARDIV	N	N	set up water purification units
Typhoon Joan	Disaster Relief	typhoon	Philippines	19-Oct-70	27-Oct-70	9	N	HMM-164, Det of BLT 2/9	12 C-130, 1 C-47, 1 C-54, C-118s, 80 sorties	N	AF: 453 evac, Navy, MC involved
Typhoon Patsy	Disaster Relief	typhoon	Philippines	21-Nov-70	24-Nov-70	4	N	N	2 C-130, 2 sorties	N	
Philippine typhoon	Disaster Relief	typhoon	Philippines	26-May-76	31-May-76	6	1 CV, 2 aux	N	4 H-3, 136 sorties	N	734 evac by AF, 1244 by Navy
Typhoon Ruby	Disaster Relief	typhoon	Philippines	25-Oct-88	25-Oct-88	1	N	N	2 H-3, 2 sorties	N	27 evac
Philippines typhoon relief	Disaster relief	typhoon	Philippines	26-Nov-90	6-Dec-90	11	1 ship	N	N	N	
Fiery Vigil (Philippines volcano)	Disaster relief/NEO	volcano	Philippines	8-Jun-91	2-Jul-91	25	CV, CVN, CVW, 2 CGN, 2 CG, DD, 6 FFG, AOR, LHA, LPD, LSD, 2 LST, LKA, AFS, AD, 3 AO, AE, AK, TAKR, 2 NMCB, CBMU, VFA, HSL, VC	15 MEU, MAGTF 4-90, 2700 troops	C-5, C-141, C-130, C-9, 246 sorties	N	Evacuation of US personnel from Clark AB after volcano, 18000 evac, Navy involved; MC: Mt. Pinatubo eruption, provided security, relief, and evac 21,000

Source: reference [12]

The most recent operation in the database was in 1991. After 1991, the U.S. military bases that were in the Philippines were closed because the Philippine Senate rejected a treaty that would have allowed a 10-year extension of the U.S. military bases in the country [19]. So, we assume that between 1992 and 2003, the Government of the Philippines did not actually invite DOD to assist in DR efforts in the Philippines. However, recently, in November 2013, U.S. military was invited to participate in the relief efforts to Typhoon Haiyan in the Philippines [14]. Assuming that going forward, the U.S. responds to disasters in the Philippines at the rate it did between 1970 and 1991, it will respond to 0.6 disasters in the average year (based on 13 DR operations over 22 years), or one disaster every 1.7 years. This is a relatively high number of disaster relief operations, suggesting that spending on them by DOD is high enough that it could be possible to generate $530,000 (the cost of the DRR project) in savings from reducing the size and/or frequency of the missions.

Just how high might spending per mission be? Data on spending on the missions in Table 9 is not available.[9] However, an upper bound on spending per mission and a sense of how spending correlates to the number of sorties flown by aircraft in a mission is given in the data on the U.S. participation in Operation Damayan, which responded to Typhoon Haiyan [14], the deadliest typhoon to hit the Philippines since 1881 [20]. Operation Damayan cost DOD $32 million, and DOD aircraft flew 1,300 relief sorties, for a ratio of dollars to sorties of $24,615 per sortie.[10] Table 9 above shows that there was one mission involving 500 Air Force sorties, another with 80, another with 136, and another with 246, in addition to three other missions that the Air Force flew aircraft in that lack data on the number of sorties, and data being missing on the number of sorties flown by Navy and USMC aircraft that participated in the missions. So, larger missions involving an average of about 240 sorties per mission ((500+136+80+246)/4=240.5) appear to be needed about once every four years;[11] at a ratio of $24,615 per sortie, these missions cost about $5,907,600 on average.

[9] Although future research could estimate what the costs were using data such as IDA's COST model for estimating contingency operations costs [18], as discussed in the DOD Spending on Disaster Relief section above.

[10] Although [14] and table 9 show that sea and ground forces also participate in disaster relief operations, we assume that total mission costs are nonetheless proportional to the number of sorties.

[11] In addition to the four missions with 500, 80, 136, and 246 Air Force sorties in Table 9, Operation Saklolo in the table lasted 26 days and involved 3 US Air Force aircraft and a USMC helicopter squadron (HMM-165), so even though the number of sorties in the mission is not known, it is likely that it was similarly large. 5 missions over 22 years is an average of about 1 mission every 4 years.

Would the air mobility training projects totaling $530,000 be able to reduce the cost of the approximately $6 million mission likely to occur within four years of the training by over $530,000? If so, this project will have positive ROI. We maintain that the answer is quite likely yes. The Philippines Air Force has just recently added five C-130s to its Air Force (three new C-130s and two existing C-130s made usable again by depot repair); its Air Force previously only had one operational C-130 [21-23]. Table 9 shows that U.S. C-130's were used in most of the disaster relief operations, with between one and twelve C-130's being used per mission. Having six C-130's in the Philippines Air Force whose crews, ground support, and command and control personnel are fully and properly trained by the U.S. in how to conduct HA/DR missions—the goal of these DRR projects—should greatly reduce the amount of support the U.S. needs to provide in the DR missions, and perhaps even reduce the number of missions the U.S. even needs to conduct. This is because the Philippines C-130s can now do the work that U.S. aircraft had done.

Given the number of C-130s, and other transport aircraft, that are being added to the Philippines Air Force, we contend that reductions in U.S. spending of well over $530,000 are likely. Indeed, assuming a 20-year lifespan of the aircraft, we think that savings of $15 million for the training project are possible. These are the savings that would be obtained from cutting in half the cost of five missions over 20 years that would have cost $6 million per mission without the training. Savings of $15 million from a $530,00 project would yield a benefit-cost ratio of 28:1—not out of line with some ROI estimates that have been found in the literature evaluating the ROI of civilian-sector projects [6]. However, future research could better measure this ROI by consulting with subject matter experts on airlift to better determine how many sorties the Philippines Air Force is now capable of per day because of the training, and how many they would have been able to do and how well they would have been able to integrate with U.S. forces in combined operations without the training. The estimated benefit-cost ratio of 28:1 above assumes that the Philippines Air Force would be unable to make any use of its new C-130s and other transportation aircraft without the training. That assumption is somewhat unrealistic.

Projects building roads to remote villages in the Philippines

The U.S. military also has recently conducted six projects building new roads and repairing existing roads that had become unusable after storm damage and lack of repair in the Philippines. These roads serve remote villages in the rural Philippines, and one rationale for the projects is that the roads improve access to and from the areas in the event of emergencies. Of course better access to facilitate commerce and so forth, is another rationale for foreign aid assistance. These roads are between two and seven kilometers long, depending on the project [2]. The total cost across projects of implementing these six DRR projects is $2,136,531 ($95,973, $675,000, $455,250, $311,500, $100,000, and $498,808, respectively).

Would these projects save DOD money on having to conduct DR missions in these areas? Would they save enough money to fully offset the cost of the projects, so they have positive ROI? Now that the roads are built, after a disaster that leaves the roads intact, or after the roads have been cleared after a disaster, these areas can be served by ground vehicles from the Philippines Armed Forces, rather than helicopters which may have been U.S. DOD helicopters rather than Philippines Air Force ones. For instance, reference [14] notes that as road conditions improved, the main responsibility for relief efforts was being passed to the Philippine military and international aid organizations.

Given that the U.S. military is likely to provide airlift support to the Philippines after disasters, as we argued in the previous case study when we looked at the historical pattern of DOD's DR missions in the Philippines, these roads will likely reduce the need for this airlift and save DOD some money on DR missions—although not necessarily enough to offset the cost of doing the projects. To estimate the likelihood that it will offset this so that the projects have positive ROI, and estimate the size of the ROI, we begin by examining data on the frequency with which disasters strike the Philippines, as above, along with data on the likely cost of the U.S. response.

How often are specific small areas, like the ones served by these roads that are between two and seven kilometers in length, hit by disasters in the Philippines? Table 8 above shows that 7,831,292 people were affected by disasters in the Philippines in the average year between 1995 and 2013.[12] The average population of the Philippines in these years was 84,033,775, indicating that in a given year, 9.31 percent (i.e., 7,831,292/84,033,775) of the Philippines population is affected by a disaster.

So we estimate that there is about a nine percent chance that a disaster will strike an area served by one of these roads in a given year. From this estimate and the estimate of the cost to DOD of its operations in Operation Damayan, we can show it is unlikely to have positive ROI, even under the extreme assumption that DOD would

[12] The definition of "affected" in these data are that the persons require DR assistance from some entity—DOD or otherwise—for basic survival needs such as food, water, shelter, sanitation, and immediate medical assistance [18].

respond to all of these disasters if the roads were not built.[13] Under the assumption that DOD would respond to every disaster in the area where a road is if the road were not built, and that if built a road has a 28 year lifespan before it becomes unusable without recapitalization, the same lifespan of surfaced and unsurfaced roads on DOD installations [24], DOD is expected to need to conduct 2.6 (i.e., .0931*28) DR operations in each area without a road where a road could have been constructed over the lifespan of the road that could have been built.

Would these 2.6 DR operations we reason are averted by building these roads have cost more than $2,136,531 in total across the operations, the cost of the roads? Operation Damayan was a $32 million operation in response to a disaster in which 17,915,713 persons were affected, and the typhoon was so much stronger than average that many roads were unusable for weeks in the areas that had them and these areas still needed airlift, unlike after a disaster in which the roads were less affected. So, the cost of an operation involving much airlift appears to be about $2 per person affected (that is, $32 million/18 million people). Across 2.6 missions, this is $5.20 per person affected. At a project cost of $2,136,531, there would need to be over 410,871 (i.e., 2,136,531/5.20) persons living in the area served by the six roads for the project to break even (e.g., for the cost of the roads to be less than the cost of the missions that are averted.)[14]

According to the OHASIS database, the number of people served by the six roads totals 36,000 persons. This is well short of the 410,871 persons that would need to be served by the roads for the project to break even, according to our estimates of the cost and expected frequency of DR missions. So, we conclude that it is unlikely that these roads projects will have a benefit-cost ratio ROI of greater than 1.0. (In fact, dividing 36,000 by 410,871 shows that these projects have an estimated benefit-cost ratio of about 0.09:1). However, future research to further refine and develop estimates of the ROI of these projects could collect data on the population of the areas served by these roads specifically, to definitely answer this question. Indeed, we recommended above that DOD ensure that data on the population served by each project be collected and made readily accessible in the OHASIS spreadsheet data. Future research could also refine the estimates of the cost of conducting DR missions in the areas if they did not have the road by (1) determining the weight and

[13] In the previous case study, we showed that DOD is likely to respond to 0.6 disasters in the average year in the Philippines, even though there are 37.5 disasters a year on average. However, because DOD responds to larger disasters affecting more people, the probability of DOD responding to a disaster affecting a particular individual or town is likely much higher than 0.6/37.5 or 1.6 percent, so we keep this assumption for now.

[14] In practice, even more persons than 410,871 would need to be served if returns years in the future are subject to a high discount factor, as is common in cost-benefit analysis [24].

volume of supplies would be needed if a disaster were to hit the area, (2) determining how many persons would need to be evacuated from the area if a disaster were to strike, and (3) estimating the cost of flying sorties to perform these supply delivery and evacuation tasks, as a function of distance between the villages and the nearest DOD air base, aircraft carrier, or flat-deck amphibious ship.

A method of estimating the ROI of DRR efforts based on vulnerability

We also developed a method of estimating the ROI of DRR efforts using data from the Notre Dame Global Adaptation Index (ND-GAIN). We explain and outline the method here and present some preliminary findings showing that when the measures in this index are improved, this is correlated with DOD performing fewer days of climate-related disaster relief missions in countries, and also correlated with fewer people dying and being affected by disasters in the country.

The Notre Dame-Global Adaptation Index (ND-GAIN) is a free open-source index that shows which countries are best prepared to deal with superstorms, droughts, security risks and other vulnerabilities caused by climate disruption, as well as their readiness to successfully implement adaptation solutions [25]. The overall ND-GAIN index is a number between 0 and 1 that measures how much damage a country is likely to get from climate disasters in the coming years as a function of:

- Vulnerability: the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change. In ND-GAIN, vulnerability includes three components: exposure, sensitivity and adaptive capacity.
- Exposure: The climate stress faced by a system or individual. In ND-GAIN it is represented by the negative impacts of climate change upon various sectors for each country, or the factors that expose sectors to those impacts.
- Sensitivity: The extent to which a sector within a country will be affected by or responsive to climate exposure. In ND-GAIN, there are sensitivity indicators for multiple sectors of society.
- Adaptive capacity: The degree to which a country is able to cope with or respond to exposed and susceptible stresses. In ND-GAIN, the indicators of adaptive capacity measure to what extent a country is capable to minimize the adverse impact of climate change.
- Readiness: The ability of a country's private and public sectors to absorb financial resources and mobilize them efficiently to reduce climate change vulnerability. In ND-GAIN, readiness takes into account economic, governance and social factors.

The components of the index are also all normalized to take values between 0 and 1. DRR projects improve metrics that improve the ND-GAIN index, particularly metrics related to adaptive capacity. Also, different categories of DRR projects correspond to different sectors of metrics within the index, such as infrastructure, water, and health.

We can show that DRR projects have benefits if countries with better values of the index and its sub-parts have less need for DOD DR operations when disasters hit, fewer deaths and dollars of property damage and persons affected by the disaster when disasters hit, and so forth. If we also know how much it costs to improve the index, and how much less the need for DOD DR operations is in dollar terms when the index increases, we can also estimate the ROI to DOD from doing DRR projects using this method.

While we do not estimate these latter two things (the costs)—it is an area for future research—in this study we were able to take a first step in this process by measuring the statistical associations (specifically, regression coefficients) between the index and the number of days DOD spent conducting DR missions in response to climate disasters in different countries, and between some of the metrics that are in the index and mission days. We also measured the correlations between values of the index for countries and the number of people who die from disasters and who are affected by disasters in the countries.

For data on DR missions, we used data on the total number of days of DR missions that DOD did in different countries between 1990 and 2000 [12]. The data show that DOD performed an average of 0.25 missions per country in the world, and the average amount of time DOD spent performing these missions was 7.42 days per country. Because DOD did not conduct DR operations in most of the countries in the world during this time period, the average number of missions is below 1.0, and among the countries in which missions were conducted at all, the average number of missions is 29.68.

Data on the ND-GAIN index is available by country starting in 1995 and runs through the present (values of the index can improve or decline over time within countries) [25]. Because our data for DR missions run from 1990 through 2000, for our analysis looking at the correlations between the index variables and mission data, we use data on the average value of the index variables by country averaged over the years 1995 through 2000. To examine whether improving the index will affect other outcomes besides mission days, we also analyzed data from the EM-DAT database on the number of people who died because of climate-related disasters in each country between 1995 and 2000, and the number who were affected by disasters.

We found that the overall ND-GAIN index has a negative correlation with the number of days DOD was tasked with performing climate-related DR missions in countries; this means that when the index is better (e.g., shows a country has a smaller amount of expected problems of being exposed to and being unable to cope with climate disasters), DOD does indeed have to spend less time (and, therefore, less money) performing DR operations. This correlation is -0.133, and statistically significant at the 5 percent level.

The correlation between the GAIN index and number of DR missions is only -0.077 and not statistically significant. This is actually consistent with statements we have heard from subject matter experts, who have told us that DOD often does small DR missions for a short time after disasters with a small number of units in order to generate goodwill towards the United States, even when non-DOD entities have the situation reasonably well-handled.

We also ran a regression of the number of DOD DR mission days performed in a country on the population size of a country (number of people) and the measures that are the four main subcomponents of the ND-GAIN index, the exposure, sensitivity, adaptive capacity, and readiness measures for countries defined above. Table 10 presents the results.

Table 10. Coefficients from a regression of the number of days DOD spends on DR missions on the four primary ND-GAIN index measures

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Regression intercept	-1.40	22.22	-0.06	0.95	-45.26	42.46
Readiness measure	-32.94	20.21	-1.63	0.10	-72.82	6.95
Exposure measure	53.22	29.59	1.80	0.07	-5.18	111.62
Sensitivity measure	46.53	23.89	1.95	0.05	-0.62	93.69
Adaptive capacity measure	-34.16	16.42	-2.08	0.04	-66.58	-1.74
Population size in country	8.46E-10	1.50E-08	0.06	0.96	-2.89E-08	3.05E-08

We found that the coefficients on all variables were statistically significant (at the 10 percent level for two of them and the 5 percent level for the others), and all had the expected sign and coefficients that are of plausible size. Higher readiness and adaptive capacity scores indicate fewer expected problems with climate disasters in a country [26], and higher scores for these metrics are associated with fewer mission days. Higher exposure and sensitivity measures indicate more expected problems with climate disasters, and these are associated with the occurrence of more days of DOD DR missions. Because the variables range between 0 and 1, and the average number of mission days performed in a country that had missions is 29.7, we contend that the coefficients on these variables—shown in the first column in the table—are sensible in size.

We also found that the overall GAIN index has a negative, statistically significant correlation with some variables in the EM-DAT database: the number of deaths per capita caused by climate disasters in the country, and the percent of the population in the country affected by disasters [18]. These correlations are negative (i.e., the better the index, the fewer deaths and persons affected); the correlations are -0.22 and -0.27 respectively, and are statistically significant at the 1 percent level.[15]

Again, these correlations and regression results are just a first step to using this method to estimate the ROI of climate-related DRR projects. To estimate ROI using this method, future research can estimate the cost of improving the ND-GAIN index measures by certain amounts with different projects, and estimate the relationship between the index variables and DOD spending on climate-related disaster relief missions. We used data on mission days rather than mission spending simply because the former was already available for use in this study. Because estimates of how much the index improves with different amounts of spending on projects can be done for both individual projects and broad categories of projects, this method can be used to estimate the ROI of both individual projects and the average ROI among projects within a category. ROI to the HNs themselves in terms of reduced amount of property damage and spending on treating those injured or affected by disasters could also be estimated. Future work could also measure the relationships between other ND-GAIN index variables—such as those for water, food, health, and infrastructure sectors in the country, given that DOD does DRR projects in many of these sectors—and outcomes. Future work could also control for other variables besides just population size in the country.

[15] We may be the first researchers to have measured these correlations between deaths and persons affected and the ND-GAIN index, correlations which help validate that the ND-GAIN index does indeed do an accurate job of measuring the risk of climate change disasters causing damage and other negative outcomes in a country: [26] states that "ND-GAIN does not include data on the impact of recent climate-related disasters. Instead, external disaster data provide an independent source of information for possible index validation."

Conclusion and summary of findings

We have conducted a proof-of-concept study investigating data and methods for estimating the ROI of DOD's climate-related DRR projects in foreign countries, and defining a path forward. Our literature review found that this topic has not been well analyzed before, at least for DOD. Our primary ROI metrics are whether and to what extent a project saves DOD money on net, by causing it to be tasked with doing sufficiently fewer and smaller overseas DR missions. We found that data and methods do exist to estimate the ROI of these DRR projects. We also found and reviewed a large literature of estimates of the ROI of civilian-sector DRR projects, and determined that some findings in this literature can be of help in prioritizing and managing DOD's DRR investments. However, there are other relevant considerations for DOD that are not addressed by the civilian sector literature. We also computed some preliminary ROI estimates in case studies for a few specific projects and found some evidence on what the ROI of climate DRR projects in general is using the data, methods, and metrics we identified.

Our preliminary estimates do find much evidence that DOD's DRR projects reduce the number and size (in terms of days of operations, number of sorties, etc.) of DOD DR missions. Reducing the number and size of the missions does reduce the amount of money DOD spends on these missions. Nonetheless, what is still essentially unknown is how often these savings are high enough to offset the cost of doing the DRR project. One of our case studies identified a DRR project providing training to the Philippines Air Force that appeared likely to save much more money in DR mission costs than the cost of the project. For the other case study on projects building roads to remote areas in the Philippines, it appeared these projects would probably generate much less savings on DR missions than the cost of building the roads.

In order for DOD to better determine how often it can save money on net by finding DRR projects that offer it a good ROI, there are further lines of research to pursue. One method is to do many more case studies than we were able to conduct in this study, and use additional sources of data, such as the official DOD cost model for generating cost estimates of contingency operations such as DR missions [17], to improve the accuracy of the estimates. We also found that there are statistical techniques for estimating the average ROI across all types of DRR projects that DOD can do, and the average ROI of different categories of projects. So a further approach is to perform a regression analysis of data on outcomes such as past DOD spending on DR mission in different countries (as well as number of deaths and dollars of property damage that are incurred in the countries) modeled as a function of past DOD spending on different categories of DRR projects, past civilian-sector spending on different categories of projects, and climate and geography characteristics of the countries that determine how many disasters occur in them.

We did not implement this approach in this paper because—although we located data on DOD DRR projects, DOD DR missions, and disaster-caused deaths, damages, and other outcomes in different countries in this study—collecting data on the other control variables besides DRR projects and finding all the relevant factors to control for was beyond the scope. We believe it is a promising approach for future research to take, however.

We also found a similar regression approach to estimating average ROI that appears somewhat easier to implement, and began implementing it in this study. This approach also would allow the ROI of specific individual projects to be estimated. This approach involves using data from ND-GAIN, which provides numerous measures of the vulnerability of countries to the effects of climate change, such as increased frequency and severity of climate-related disasters. Doing DRR projects improves the measures in this index. This approach has an advantage over the other regression approach outlined above in that the index variables already measure a very comprehensive set of factors that measure the frequency and strength with which climate-related disasters occur in different countries as well as myriad factors affecting how much damage they are likely to cause, including the output of DRR projects of many different types that were done in the country. So, this approach uses data that already has collected enough information to avoid the omitted-variable bias (i.e., incorrectly estimating the return on investment because some important factors affecting outcomes are not incorporated into the analysis), as opposed to the other regression approach, which would require a large data-collection effort to avoid the omitted-variable bias.

We show that improved measures in the ND-GAIN index variables have statistically significant associations with better climate disaster-related outcomes in countries such as DOD being tasked with doing fewer days of disaster relief missions in the country, and the country experiencing fewer deaths from disasters and having fewer persons be affected by disasters (i.e., requiring assistance from emergency responders after disasters). Future research could estimate how much different types of projects with different costs improve the index and correlate the index data with DOD spending in countries on conducting disaster relief missions, as well as spending by these countries' governments and civilian-sector NGOs on DR, in order to use this approach to estimate the ROI of DRR projects. Again, this approach can be used to estimate both the average ROI of types of projects, and also the ROI of individual projects, because individual projects can be evaluated for how much improvement in the index they produce per dollar. Further, the ND-GAIN index data contain measures of climate-disaster-resiliency for many for different sectors of countries including indexes in the water, health, and infrastructure sectors, which are sectors that DOD has done many DRR projects in. So, it is possible to estimate the average-across-projects returns to categories of projects within these sectors with this approach.

We recommend that DOD take steps to improve ROI estimates and the process of obtaining them by collecting additional data on project scale—number of persons served by projects and measures of the extent to which they are served by projects—and making the data readily available in spreadsheet form on proposed and funded DOD DRR projects in the OHASIS database that DOD currently uses to collect information on the projects. This additional information would make it feasible to estimate the ROI of individual projects with the regression approaches outlined above, rather than just average ROI across projects within a category. Outcomes measured in the ND-GAIN index variables, such as number of persons with access to improved water supply (DRR projects can increase this number), would be good measures of the extent to which people are served.

Although the average ROI of different categories of DRR projects can be estimated, the civilian-sector literature cautions against prioritizing by category of project alone when deciding which proposed projects to fund. That is because it has been found that ROIs vary greatly between projects within a category, so that an approach prioritizing individual project proposals for funding according to highest expected project-specific ROI will pick a portfolio of projects with a higher ROI across the portfolio than prioritizing by categories with the highest average ROI across projects within the category [6]. So, we recommend that DOD prioritize projects based on ROI estimates specific to individual projects whenever feasible.

In the absence of individual-project-level ROI estimates, we contend that the country-level metrics measuring mortality risk from natural disasters and country-level measures of the percentage of the population affected by drought identified by other literature on civilian-sector DRR projects would be helpful for DOD to use in prioritizing projects. These metrics are clearly related to disaster risk and directly measure risk of exposure to disasters.

Our review of the literature on the ROI of civilian-sector DRR projects did discover one positive finding: many if not most of DOD's DRR projects are likely to have good ROI in terms of benefits to the HNs, from the projects creating savings by reducing deaths, property damage, injuries requiring medical care, and the number of persons who require emergency assistance after disasters. This is because DOD conducts many DRR projects that are the same as or similar in nature to those that civilian-sector entities often do—such as flood-prevention projects—and because the large literature on civilian-sector DRR efforts has found that about 85 percent of the projects it has evaluated have positive ROI, often with benefit-cost ratios of two or higher. So, regardless of what savings DOD recoups from DRR projects in terms of being tasked with doing fewer DR missions, the military can be confident that its DRR efforts are benefiting the host countries and providing productive TSC support.

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