MEASURING THE EFFECTIVENESS OF WATER FUNDS

GUIDANCE DOCUMENT FOR DEVELOPMENT OF IMPACT MEASURES

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TABLE OF CONTENTS

MEASURING THE EFFECTIVENESS OF WATER FUNDS
Monitoring Proposal

Introduction

The purpose of this document is to bring together over a year of collaborative effort in designing scientific protocols for monitoring the impacts/outcomes of the water fund strategy which is rapidly replicating and proliferating throughout TNC priority sites. Water funds have a variety of subject-area goals related to hydrology, biodiversity, socioeconomic, governance, and financial themes. This document will:

1) Briefly introduce the *basic water fund model*;
2) Provide a *framework* for linking water goals and strategies to measures of actions and outcomes;
3) Present an *experimental design* for measuring water fund impacts; and
4) Develop a set of more *detailed protocols* with experimental questions and potential indicators (summarized in a series of look-up tables) that could be used to test water fund activities' effectiveness. In some cases, example methodologies will be offered (in appendices).

We intend this document to be broad enough to apply beyond one water fund site. Specific scientific protocols were intentionally omitted or are referenced only in appendices as we expect local experts in each water fund site to select the most effective protocols and materials to document impacts.

Please NOTE: For ease of formatting all of the look up tables (Tables 1-3 and all component parts) are located at the VERY END of this document – after the appendices.

Part 1: Water Funds Basic Model

What is a water fund?

Payments for watershed service projects make up a significant portion of implemented payment for ecosystem services schemes (many others relate to carbon). These schemes often involve water users paying "suppliers" for the delivery of clean, consistent water supplies. Water funds now proliferating throughout the Latin American region of TNC, do exactly that – link downstream water users with the source of their clean regular water supplies. Water funds originated in the Northern Andean region where headwaters of rivers important for numerous downstream users originate in higher altitude natural ecosystems (composed of native grasslands, páramo, and mixed forest). These ecosystems serve as the hydrologic regulators for the entire water system.

The situation in these Andean systems that lead to water fund design are three-fold: growing populations of downstream users require increased flows of services, the natural ecosystems that provide the services are not sufficiently protected, and the human communities that threaten the natural ecosystems are poor and depend upon these ecosystems for their livelihoods. In addition, their land use practices can have their own consequences for service provision, as farming and ranching can lead to reduced water retention and increased water pollution. But, water services can't be preserved solely by keeping people out of the natural areas and restoring the working landscapes, as this would compromise many livelihoods. Using an ecosystem services framework, TNC and partners used the dependence of downstream people on the services provided by natural ecosystems and restored working landscapes to finance conservation and livelihood projects to secure water services sustainably – i.e. water funds.

Water funds are a public/private partnership focused around a long-term, sustainable finance source for conservation. Water users voluntarily invest money in a trust fund, and the revenue (interest and often part of the principal) from it is used to initiate conservation projects in the watershed. Water users include water utilities, hydropower companies, bottling companies, beer companies, and sugar cane producers, among others, depending on the fund. In various water funds, other key stakeholders (even if not donors to the fund) also get a seat on the board, including local watershed community representatives. The projects the water funds finance take steps to address the needs of preserving natural ecosystems and maintaining the well-being of watershed communities.

Financed activities and projects can include hiring community-based park guards to maintain the natural areas (to maintain the natural hydrologic regulation of the system, which helps maintain a regular base flow), protecting riparian areas (putting fences up to keep crops and cows away from river banks), re-vegetating riparian areas (to provide a natural filter for sediments and other pollutants), planting live tree fences to delineate property boundaries, and isolating/fencing off headwaters and steep slopes. These practices can have major impacts on water quality, on the timing and volume of water flows (particularly floods), on fires, and on freshwater biodiversity. One study demonstrated that just maintaining natural vegetation on the landscape can decrease sedimentation tenfold compared with converting the area to cropland.

Such management is not without costs, however, and thus the water fund not only finances conservation management projects but also supports community projects to compensate for impacts on livelihoods. Ideally, conservation management activities will enhance farm/ranch productivity through the production of on-farm ecosystem services such as soil stabilization and enhanced soil fertility, but these benefits will not be immediate and are not guaranteed. In the shorter term, conservation management agreements include livelihood investments such as environmental education programs, additional income sources such as guinea pig farms, alternative food sources such as organic vegetable gardens, and expanded capacity for the production of goods such as providing communities with ovens to make the drying of fruit and herbs they sell on the market more efficient and effective.

Water Funds Objectives

To develop an effective monitoring program, water funds impact measures must monitor and measure the impact of individual conservation activities/actions (these are site-based interventions) but also the impact and effectiveness of the strategy more broadly. Each individual activity implemented on the ground as its own objective which contributes to the broader objectives of the overall strategy. In addition, specific, quantifiable objectives will vary from fund to fund. In this guidance document we use a generalized set of objectives common to most water funds to explore best practices for the design of impact measures.

Thus, generally, water funds are a strategy that takes a landscape-scale, watershed approach to conservation in order to:

1) improve or maintain water quality and secure regular flows of water quantity for downstream users;
2) maintain regular flows of water throughout the year;
3) maintain or enhance freshwater and terrestrial ecosystem biodiversity; and
4) improve or maintain the well-being of upstream human communities.

Using watershed conservation as a common objective water funds create:

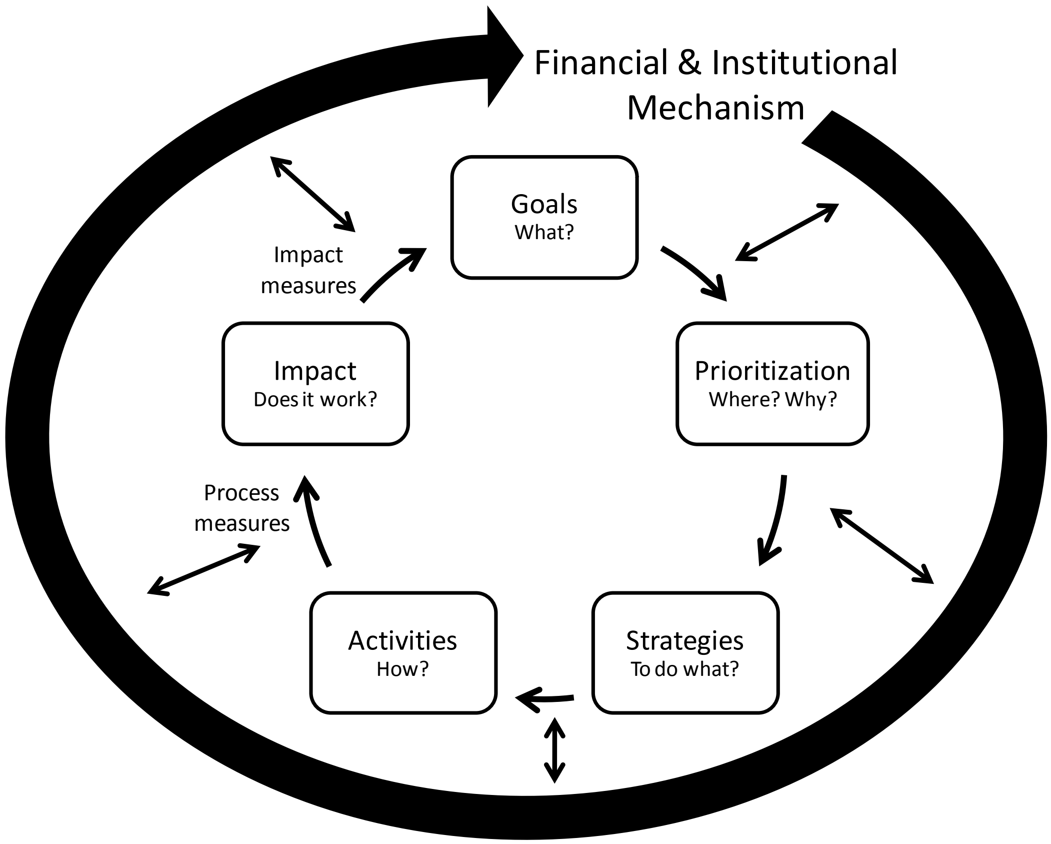
5) a multi-institutional governing body of public and private partners;
6) opportunities to avoid costs of water treatment by investing in nature instead of infrastructure; and
7) sustainable financing for long-term conservation efforts.

Part 2: The Framework

Water funds have multi-disciplinary goals using a variety of financial, institutional, and biophysical components to achieve those goals. Monitoring of water fund impacts not only need to measure progress towards each objective, but also demonstrate how achieving each objective collectively contributes to the effectiveness of the entire approach. Figure 1 presents a general framework for thinking about these components. The inner circle represents the actions and activities that are occurring on the ground in the water funds. Please note throughout this document we will use the terms actions and activities to refer to conservation interventions financed by the water fund trust fund – in other words the actions and activities associated with protection and restoration of ecosystems.

None of these actions would be possible without the outer-circle – the financial and institutional mechanism driving the water fund as this is the source of revenue and the source of decisions on what actions to take where. Measures need to be designed to assess the effectiveness of the inner circle on-the-ground actions AND the effectiveness of the institutional and financial mechanisms. Together these measures will determine water fund effectiveness. If functioning, the institutional model (or public-private partnership described in the previous section) should be able to and should alter the various components of the inner circle if the prioritization was wrong or an activity is not having the desired impact, for example.

Figure 2 – General Framework/conceptual model for a functioning water fund



The inner circle of Figure 1 deals with on-the-ground impacts. Using various scientific and technical tools (see Goldman et al. 2010 water fund report and Ramos et al. water fund manual *forthcoming* for more details) various water funds have produced maps of service provision from the landscape to allow for prioritization of what activities to put where. In these priority areas, different strategies are developed and acted upon using various conservation activities and actions. These activities and actions can be tracked using process measures (how many meters of fencing, how many families are participating, etc), but ultimately each action should be linked directly back to the overall goal which, in the case of water funds, is more than just an action; it's an outcome. For example, one water fund goal is a clean, regular supply of water. Thus, it is necessary to not only know how many fences have been built (process measure in Figure 1) but if those fences help provide cleaner water – the desired impact which requires developing impact measures.

The rest of this guidance document will be focusing on more detailed experimental frameworks for measuring specific indicators to track impacts of water fund investments, but it is essential to keep the larger framework in mind (Figure 1) as this helps connect the measures taken for individual on-the-ground activities (such as fencing) with the broader understanding of testing the effectiveness of the overall water fund approach in achieving its objectives.

As mentioned, these measures operate at different scales. Due to the wide range of on-the-ground actions that aim to achieve one or more goals of the overall fund, monitoring might need to occur in some places on a relatively small scale to ensure effectiveness of a particular action (e.g. does fencing cattle out of waterways lead to decreased sedimentation in the water) recognizing that the outcome from that action links directly to a broader water fund objective (e.g. delivery of clean water). To make this relationship more transparent, we developed a series of tables and figures (results chains) for several water fund strategies (see Figures 2 and 3 below, respectively).

For example, in the case of the goal improving water quality water funds have a variety of actions they deploy: strengthening the protection of protected areas, reforestation, and improved management of crop and ranch land, among others. Figure 2, below, chooses one of these strategies : improved management of crop and ranch land and in tabular form shows how on-the-ground actions taken to achieve this strategy relate to indicators that can be used to ensure desired impact. Figure 3 displays this same relationship in a results chain framework. Tools such as Conservation Action Planning and Miradi can be very helpful in developing and depicting these relationships (see Appendix A for two other examples with different water fund goals and strategies).

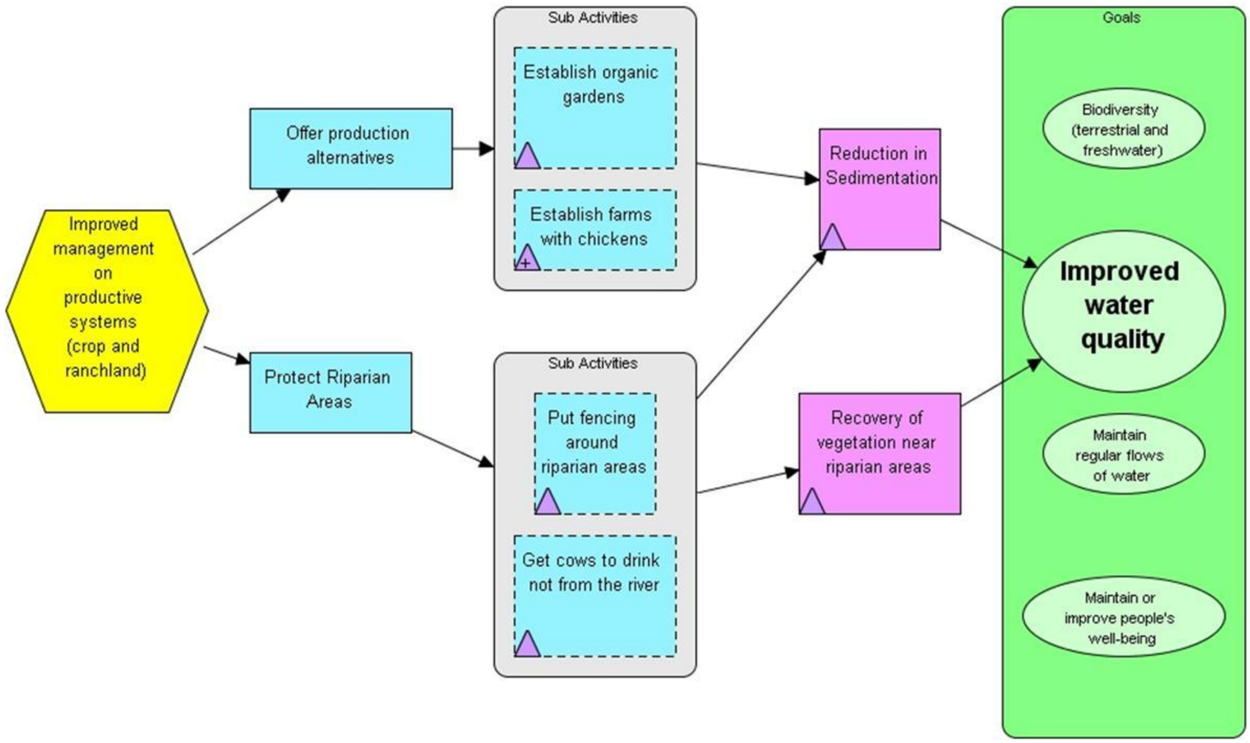
The main purpose of Figures 1-3 is to relate small-scale activity-based impact measures to the broader water fund approach – literally demonstrating how measuring and monitoring the impact of small scale strategies helps demonstrate the effectiveness of the overall approach.

Figure 2 – Tabular depiction of water fund process

Goal: Improve Water Quality

Strategy	Activity	Activities			Impact	
		Sub-Activity	Indicator			
			Process	Threat reduction	Desired impact	Impact Indicator
Improved management on productive systems (crop and ranchland)	Offer production alternatives	Organic Gardens; Give Chickens	Number of gardens; number of chickens; number of families with chickens	Number of cows in the headwaters	Reduction in sedimentation	Quantity of Sediments
	Protect Riparian Areas	Put fences around riparian areas	Number of meters of fencing	Number of cows that drink out of the river	1) Reduction in sediments before and after fence 2) Re-growth of riparian vegetation	Macro-invertebrates?
		Have cows drink from other locations	Number of drinking tubs			

Figure 3 – Linked chain/results chain depiction of water fund process (note: indicators are hidden)



Part 3: Experimental Design

After establishing the important links between water fund goals, strategies, activities, and impacts, the next questions is how to measure the impacts of the activities. Water funds use multiple local-scale actions or projects (e.g. fencing, reforestation, protection, livelihood projects) in a given watershed in order to have a more regional-scale impact on water services (quality, quantity, and flow) and biodiversity conservation. The first step in developing monitoring protocols to measure the impacts of these projects is to create an experimental design. The experimental design should aim to answer a set of general questions that, can assess whether the water fund model is functioning all or in part as intended.

Broad Questions/Water Fund Goals

1) What is the value added to water quality, water flow, biodiversity, and human well-being from the water fund?
2) What are the impacts of watershed management activities and watershed conservation strategies in advancing water fund goals:
    1) Provide clean, regular supply of water.
    2) Protect and enhance terrestrial and freshwater (FW) biodiversity
    3) Protect and enhance people's well-being
        1) Clean, regular water supply
        2) Rural livelihoods and productive systems

Other important questions to keep in mind while developing and implementing impact monitoring include:

1) What percentage of a watershed needs to have water fund actions implemented (e.g. best management practices) before there is a measurable downstream effect? What is the minimum size of the area under water fund intervention to affect a minimum detectible change downstream at the sub watershed level or at the basin level?
2) How many sites and how many replicates and at what scale do we need before we can make some general conclusions about the effectiveness of this strategy?
3) How do we get a sense for the conditions under which water funds have a higher probability of making progress towards their goals?

Controls

It is essential to ensure that any impacts we see can be attributed to water fund investments and not other external variables. Therefore, our general experimental design is predicated on having some form of control. We need to understand to what extent water funds help us achieve our objectives and evaluate how certain we are that water funds (and not some other factor) caused the impacts we observe. Once these direct links have been made, there will be no need to "prove" that the actions work, and monitoring can focus on the extent to which objectives are being met.

Scale: Monitoring and Measuring the sum and the component pieces

As discussed, water funds are an approach that use relatively small-scale (parcel-based or multiple communities) actions to generate landscape-scale impacts (basin-scale). Both levels of impacts need to be monitored and measured ensuring that desired services are being delivered at the scale at which users are concerned. For example, water funds provide incentives for people living in the water shed to avoid degradation of natural ecosystems and improve management of their working landscapes by fencing off cattle from rivers and headwaters. At a local scale, it's important to ensure these chosen actions are improving or maintaining biodiversity, water quality, and regular water flow regimes. At a basin scale – at the point of out-take by water users, it's important to ensure these actions are being implemented extensively enough that there are measurable benefits compared to watersheds with no water funds investments.

Thus, we divide the last part of this document into two subsections. In the first, we described a quasi-experimental design using a paired watershed approach to track key indicators across multiple water funds – essential for regional-scale monitoring and ensuring the effectiveness of the approach across multiple basins. In the second, we describe more detailed measures of conservation actions and other water fund activities – both biophysical and socioeconomic – which we suggest are thoroughly monitored and measured in a few key water funds smaller-scale areas to ensure actions are delivering desired services.

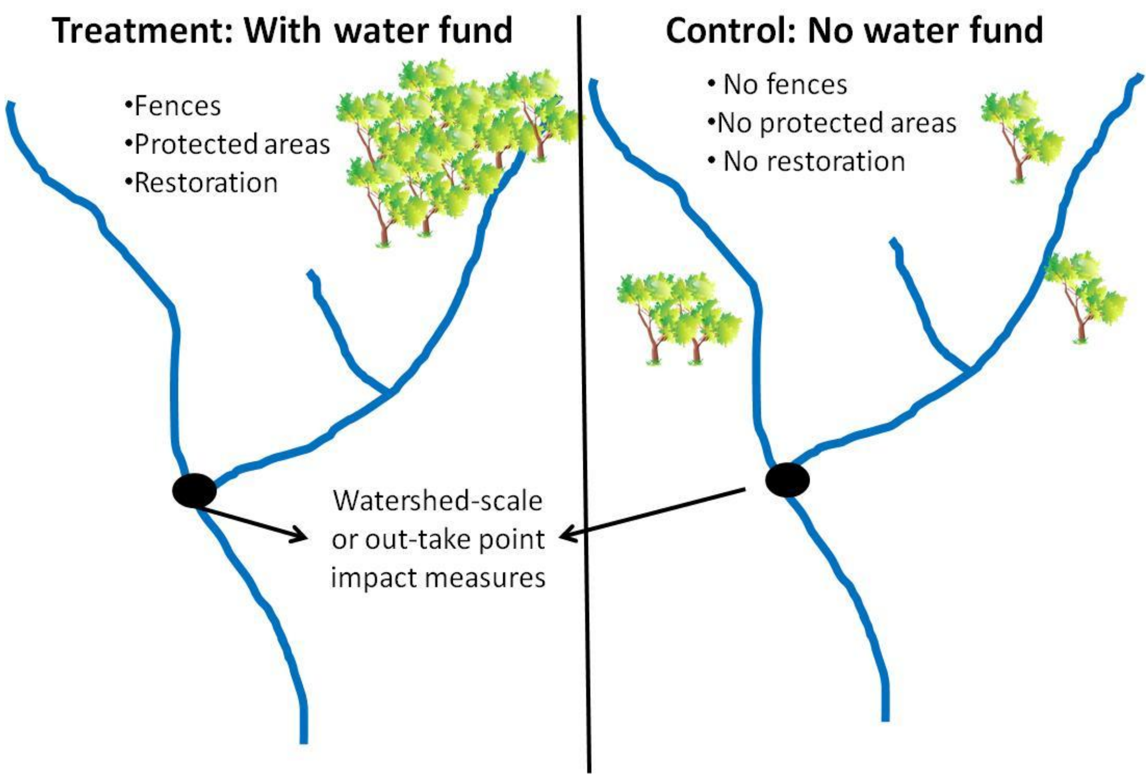
Part 3a: Paired Watershed Approach (Measuring the Sum)

Larger-scale impact measures are designed to look at the impact of the water fund investments at a larger basin scale. The best site for measuring these impacts will depend on the fund, the scale of the work, the number of watersheds filtering into the out-take points, etc. Ideally two very similar basins can be identified – one for a control and one for an experimental site. Types of questions this scale of measures will answer are:

1) What is the effectiveness of investments in improved ecosystem management on working land systems and conservation of native ecosystems in the watershed on achieving water fund goals?
2) What percentage of the watershed must be under water funds activities to make an impact?

The control must be a catchment relatively similar to that of the water fund watershed but where no water fund investments are made (see Figure 4 for a basic depiction). To answer the large-scale experimental questions, selected indicators would have to be monitored at the outtake point – i.e. the point lower in the watershed where the water reaches the users. Likely one or more of the water users are taking data at this point already in the experimental watershed site. It is critical to review the types of equipment already in place, indicators being measures, and geography of the equipment to avoid duplicating efforts.

Figure 4 – Treatment and Control for large scale effectiveness measures



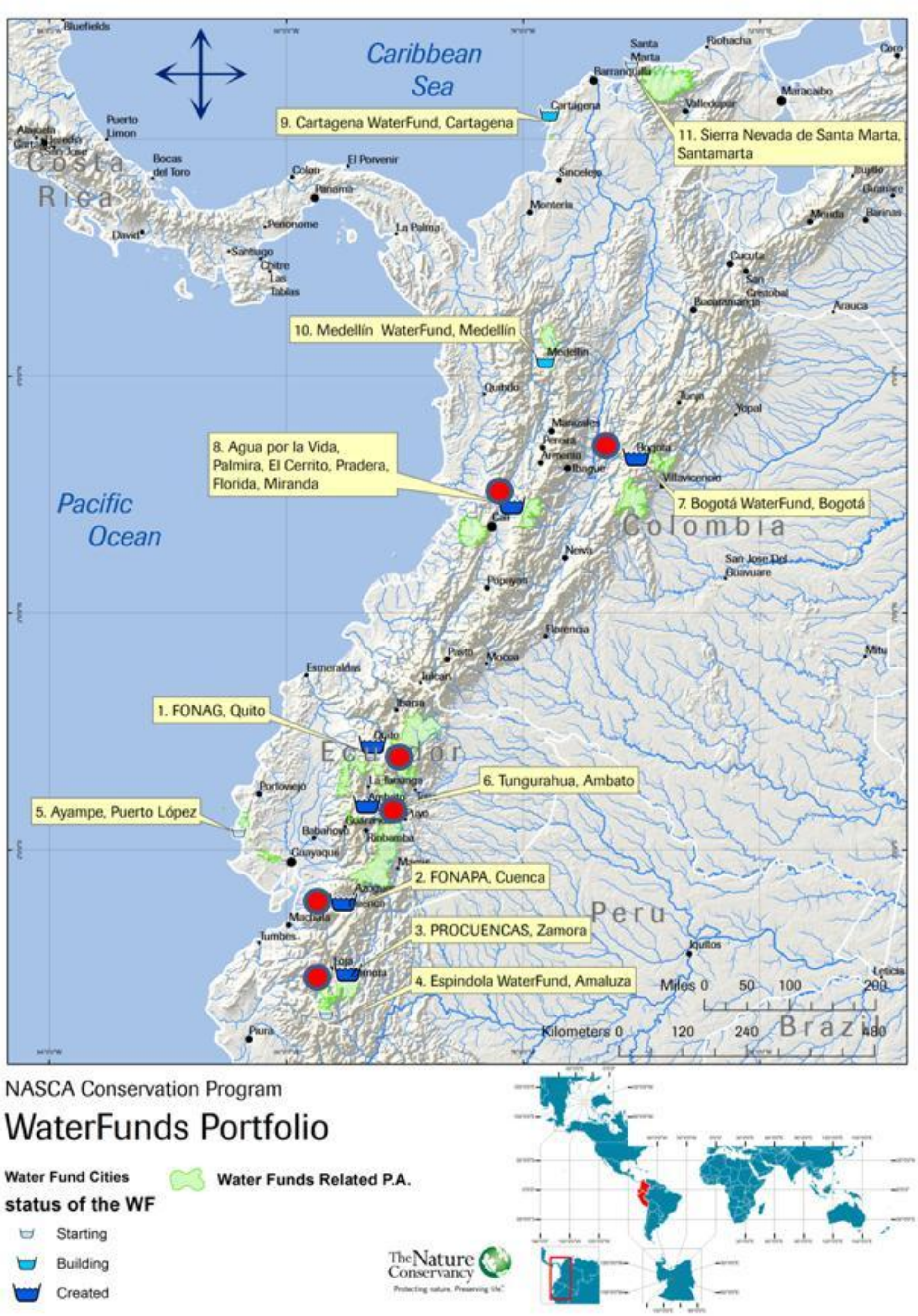
At this scale, the main objectives of the water fund are delivery of clean, regular supplies of water to the downstream users. The actions taken in the watershed should be delivering these services. Thus, impact monitoring should focus on key water quality and water flow regime indicators and provide measures of status and progress towards objectives (Table 1a-c). There is a wide variety of equipment that can be used to monitor many water flow and quality parameter. At this scale, we recommend the use of continuous monitoring equipment (e.g. third row of table 1a) rather than a less automated methodology. Continuous, automated measures will more effectively capture the variation between water flow and quality as compared to a control at the scale of the basin. Even within the realm of continuous measures taken by fairly automated equipment, there is a wide variation of equipment. Given these many options, it can be relatively inexpensive to monitor across multiple basins (see Appendix B Hydrology section for some examples).

Answering questions such as the scale to which basins must be conserved before an effect on important indicators can be measured can be difficult to measure with just one control and one treatment watershed. We recommend a paired watershed design (see Figure 5) where across existing water funds we use similar equipment (preferably) to measure the basic indicators in Tables 1a-c (research questions and design will be discussed in more detail in part 4 in the hydrology section). Given that water funds are already selected this will be a quasi-experimental design. Control watersheds are essential. Using existing GIS-based maps, watersheds should be as closely matched in terms of basic environmental attributes: slope, precipitation, soil type, land use, etc to ensure control sites provide a good basis for determining water fund benefits.

Figure 5: Example of paired watershed design (n=6 here but could be more) : How do TNC NASCA water funds affect water supply?

Out-take point of watershed with water fund

Out-take point of similar watershed without water fund



Part 3b: Small-Scale Activity Measures (Measuring the Component Pieces)

At a smaller scale, water funds use a variety of actions to achieve the basin-scale or watershed goals described previously. These measures require more detailed monitoring of on-the-ground biophysical and socioeconomic investments. These measures need to be appropriate for the various ecosystem types and the various actions taken in each water fund.

Defining the ecosystems and actions

In the watersheds of the Northern Andes with active water funds, we find three major land cover or land use types: 1) páramo, 2) forest, and 3) working lands. Working lands are lands being used by people living in the watershed for production including crops and cattle ranching. These lands are generally being used in ways that are affecting the capacity for the natural ecosystems to deliver a variety of services most efficiently and effectively.

Water fund projects have three main courses of actions to help achieve their goals: 1) conservation of native ecosystems, 2) improved management of working landscapes (ranching or cropland), and 3) community-developed livelihood projects. Conservation of native ecosystems includes protected area management as well as conservation of native vegetative patches. Most of these areas surround the headwaters of key surface flows. The rest of the watershed tends to be working landscapes with natural ecosystems in varying degrees of degradation.

We need to think about measuring the impact of common water fund actions to conserve and restore watershed landscapes and to maintain and/or to improve human well-being:

1) Hiring park guards to ensure protection of páramo and forest,
2) Implementing best management practices on working landscapes such as fencing riparian areas, re-vegetation, and planting live fences (trees), and
3) Livelihood projects that include income diversification and resource access such as organic backyard gardens and guinea pig farms.

For each of the landscape type (natural ecosystems and working landscapes) there are often gradients of degradation, starting with intact systems and passing though many levels of degradation to reach states that are significantly altered from their natural condition. Multiple strategies will be applied within a given watershed as the source of threat varies by the state of the system – e.g. park guards are useful for keeping cattle out of protected páramo while best management practices are appropriate for working landscapes in a given watershed. Here we present an example of how an experimental design would break down the indicators and measures by scale.

Experimental Questions

At this scale, the basic question that can be asked is:

- Does a particular water fund activity (examples include fencing riparian areas, fencing headwaters, planting trees) have the impact we expect or hope for?

This means we are testing the effectiveness of a particular activity – the sum of these interventions being the main objectives of the fund. For example, the productive systems in one of the water funds could be small-scale cattle farms and the main strategy employed by the water fund for reducing degradation of water services would be fencing off riparian areas to keep the cattle out of the water and allow vegetation to re-grow, the idea being this riparian vegetation could provide a natural filter for sediments and fecal coliforms. We want to know: what is the effectiveness of fencing?

METHODS

Systematic Review of Literature and Meta-analysis

Prior to spending too much time and money in a particular watershed monitoring the impact of water fund investments, a meta-analysis to assess the body of evidence on the interventions should be conducted. This meta-analysis should be based on a systematic review of available literature including both academic and non-scholarly literature. Having this evidence assembled will cut way down on the burden of proof for needed monitoring on a more site by site or parcel-scale basis saving time and money as fewer replicates and controls sites will be needed. A guide to conducting such systematic reviews is available from the Centre for Evidence Based Conservation (www.cebc.bangor.ac.uk), and a library of such reviews is maintained through the Collaboration of Environmental Evidence (www.environmentalevidence.org)

Depending on the amount of evidence acquired about the success of a particular intervention, only one or two water fund sites might need to go into detailed monitoring about the impacts from a particular strategy.

Site-selection: Choosing water funds for measures implementation

TNC already has numerous water funds in operation and many more planned and in design phases. Ideally the choice of water funds where in-depth smaller-scale measures/monitoring would occur randomly to avoid selection bias. This is often not possible given funding constraints and the need to be opportunistic when funding arises, but if possible, it would be ideal for these small scale measures to occur in a stratified manner covering the major variation between the water fund geographies. This means identifying what might be the most important characteristics of variation between the water fund sites – e.g. size of watershed, land uses, ecosystem types, slope, population living in the watershed, etc. Then, sites would be selected to cover this range. For example, if the greatest variation between the water fund locations is the size of the watershed, then ideally, small-scale measures would be done in a randomly selected small watershed, a medium watershed, and a large watershed. Recognizing that this is not always possible, it’s important that any reported results reflect selection bias that may occur. Lack of randomization means results should be reported as case studies where monitoring data “provides evidence for” or “supports” a given conclusion rather than concretely “shows” results are one way or another.

The number of water fund sites where small-scale measures are required depends on how variable the sites are. Statistical analyses require **a minimum of 3 water fund sites** with in-depth small scale measures. At **least 3 replicates** are required in all cases for statistical conclusions to be made and the actual number of replicates required for robust the results depends on how much the most important indicator you are trying to measure varies across the landscape.

Monitoring Design and Data Analysis

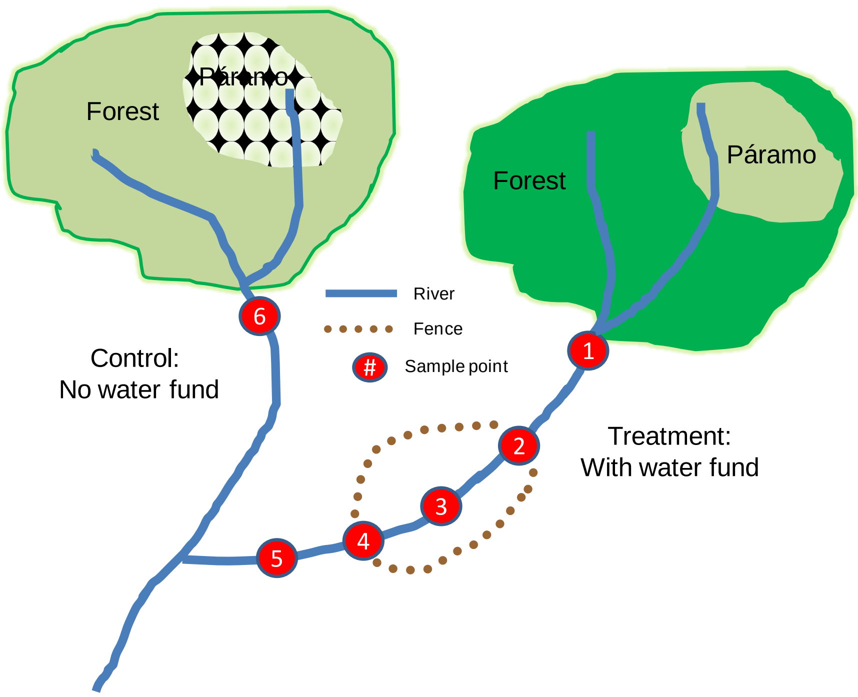
In the case of smaller-scale activity based measures, responses may be relatively rapid and controls are often more easily selected. A control site should be basically the same as the site where you are doing the water fund-related activity, just lacking that activity. Controls are needed to ensure that whatever change we are or are not seeing is due to the fencing and re-vegetation and not some other external phenomena (e.g. a very dry or wet year). Often control sites can be within the same area or sub-watershed of the water fund if there are enough different communities and landowners some who are participating and some who are not. By selecting controls from the same watershed, you usually minimize geographic, environmental, and cultural variation. The number of replicates and number of controls will depend on the inherent variation in what you are trying to measure and the level of accuracy and proof needed/required. The latter may be determined by the degree of evidence in the literature, amount of money available to do the study, and the risk associated with the projects.

Impact measures are needed for hydrology indicators (similar to large-scale measures described previously) namely water quality and water flow regime, for terrestrial and freshwater biodiversity, and for socioeconomic factors. Exact indicators and methodologies will vary by site, available expertise, and available funding. Finally, different experimental designs will be required based on the impact being measured (biodiversity versus socioeconomic versus hydrology) and where in the watershed impacts are being measured (protected areas or working landscapes).

Figure 6 illustrates a basic experimental design for measuring the impact of different water fund interventions on hydrology indicators (see Part 4 for sample indicators). The green areas are natural ecosystems, as labeled, with the lighter green being more degraded, unprotected natural ecosystems (i.e. the control site). Sample points 1 and 6 would measure water quality and water flow regime indicators (see Part 4 – hydrology) to compare impact on flow and water quality from removing cattle and increasing protection of protected areas. Sample point 6 would be the control site– where no water fund actions (e.g. no extra park guards) are occurring - for sample point 1, the experimental site allowing for a basic BACI (Before-After-Control-Impact) assessment (see Figure 7).

Sample points 2-5 represent a means to measure the effectiveness of fencing and/or planting of riparian vegetation on flow regulation and improvements in water quality using a pseudo-control – Sample point 2. If the area fenced is long, then it might be ideal to measure points within the fenced area (between sample points 2 and 4) – such as point 3 - as well as after the fencing (sample point 5) to more accurately measure the response of the indicators (see Figure 8a) across a range of sites. If the fenced area is relatively short, then points 3 and 4 can be excluded and a basic BACI design and analysis might be more appropriate (see Figure 8b).

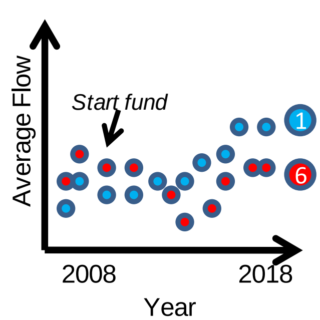
Figure 6 – Example Experimental Design for watershed investments for hydrologic Indicators



Data Analysis

There several types of analyses that could be generated using the proposed monitoring design in Figure 6 depending on how the sampling was done. Points 1 and 6 measure the impact of conservation of protected areas on key hydrologic indicators. Ideally, these measures would be started several (preferably 5 or more) years before water fund implementation to have some idea of how these indicators vary naturally (i.e. without any experimental treatment). Then, when the activity starts (e.g. park guards are added), the BACI design could be used to understand how a key indicator – such as water flow – varies year-to-year, but varies in a different way with the presence of a water fund activity (see Figure 7 for an example where flow is different each year, but the control area #6 begins to report consistently lower flow than the treatment area #1 only after the water fund activity commences. Such measures would be an average of the data taken from all measures of the indicator at that site.

Figure 7: An example of the data analysis that could be done using the BACI design described above where blue dots are "with water fund" and red dots are "no water fund – i.e. control"



Points 1-5 can be used to assess the effectiveness of an intervention over space or geographical extent (a gradient). The variation in an indicator, such as fecal coliforms (see Figure 8a), can fluctuate with extent of conservation intervention (such as fencing). This type of analysis gives a measure of how the length, quantity or extent of an activity might impact the indicator of interest using a pre-treatment measure (point 2) as a pseudo-control. If the length of fencing is short or the variation in an indicator within the fencing is of less interest then just points 2 and 4 could be measured using a BACI design (making the assumption that point 2 is the control) – see Figure 8b.

Figure 8a and 8b

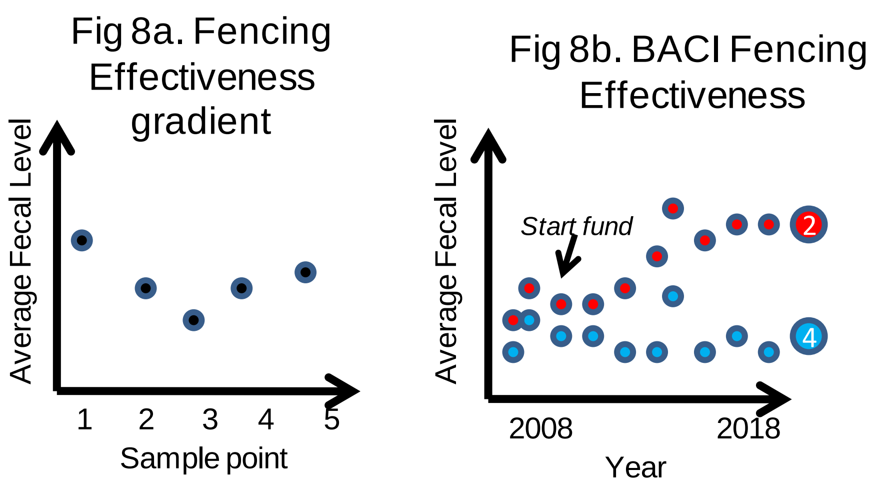
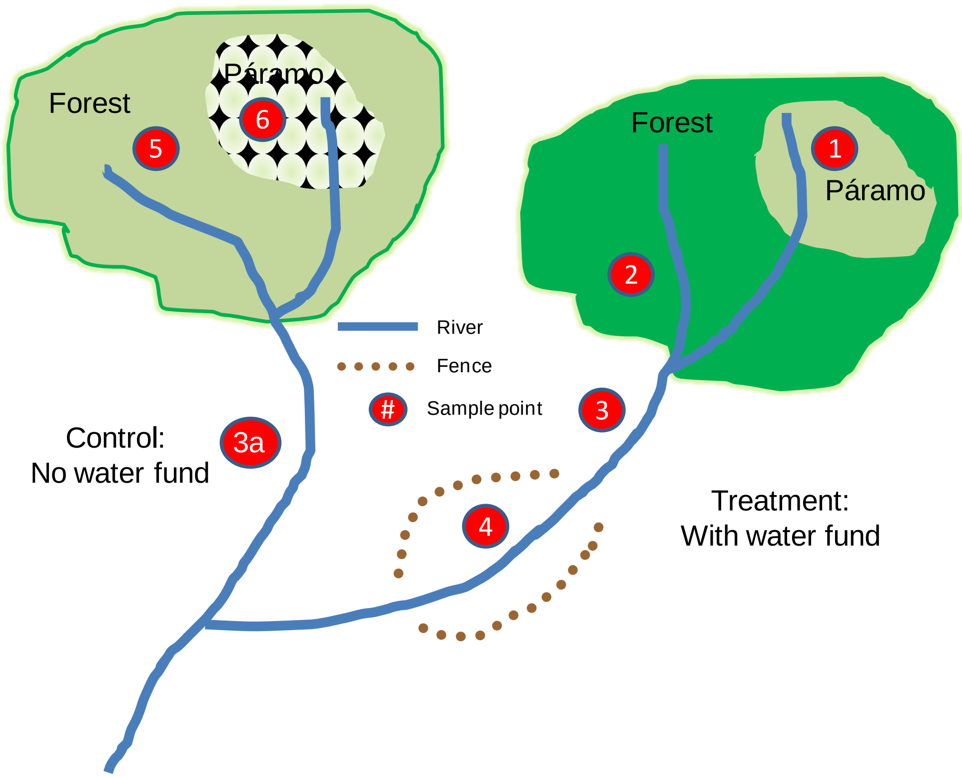


Figure 9 demonstrates a general experimental design for other indicators such as terrestrial and freshwater biodiversity and socioeconomic indicators (see detailed protocols in Part 4, below for possible indicators and detailed methodology). Again, control sites are needed. If watersheds are large enough and there are a number of communities participating and not participating in the water fund then the control sites for some of the indicators may be found in the same watershed – Sample point 3. If, however, this is not true, then a control might need to be sought in a watershed that is as similar as possible to the experimental watershed – Sample point 3a (similar to the control for the large-scale measures described previously). Please note that all measures would require multiple replicates. For example, at sample point 3 multiple transects (**minimum of 3 but perhaps more depending on the inherit variation of the factor you are measuring**) would be sampled and the same at point 2, 4, etc. Thus sample points simply represent areas for transects and measures to be taken.

All sample points in this design could be used to monitor impacts on freshwater and terrestrial biodiversity. This monitoring involves transects that can stretch across the riparian area measuring impacts on the land and in the water (see freshwater and terrestrial biodiversity protocols in Part 4, below). Monitoring should be stratified by habitat type, or taken in páramo and forests (those protected by the water fund and those not protected by the water fund), working landscapes with no best management practices, and working landscapes with best management practices to develop measures of impacts of the interventions. Sample points 3 and/or 3a and 4 would be the control and treatment sites for socio-economic and community monitoring where the points would represent communities not participating or participating in the water fund, respectively.

Figure 9. An Example Experimental Design for watershed investments for biodiversity and socioeconomic Indicators



Data Analysis

Sample points 5, 6, and 3 and/or 3a would be the control sites for sample points 2, 1, and 4, respectively. As described previously, these measures would be a BACI design tracking the change in the indicator through time expecting to see an unprecedented variation between the average measures of the control and experimental sites. For example (see Figure 10a), in the case of freshwater biodiversity we would expect to see greater macroinvertebrate richness in site 4 as compared to site 3 (or 3a) over time. If sufficient pre-water fund activity (before) data is not available to carry out a BACI analysis, the number of sample points in each habitat type (protected and unprotected forest and páramo, and working landscapes with and without water funds) should be increased to **at least 3** (or more depending on the variation of what you want to measure), then an analysis of variance (such as an ANOVA or non-parametric alternative) may be used (Figure 10b).

Figure 10a. **Example of BACI analysis that could be done for each indicator in the experimental design in Figure 9. This example shows what results *might* look like for macroinvertabrate analyses.**

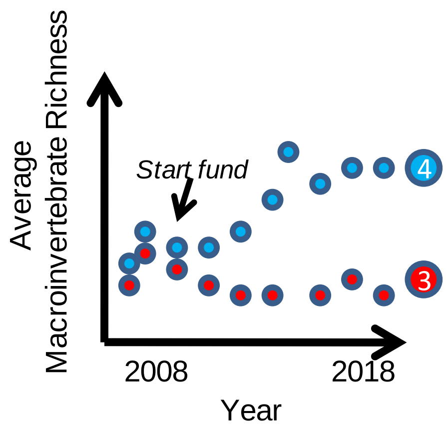
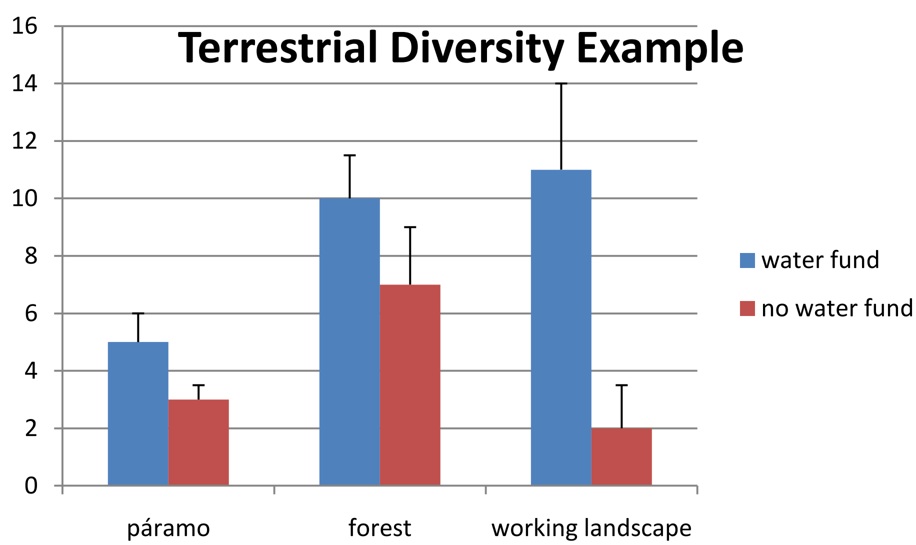


Figure 10b. **Example of analysis of variance (ANOVA) type analysis that could be done for each indicator in the experimental design in Figure 10 if sufficient before data was not available to conduct a BACI. This example shows what results *might* look like for terrestrial diversity analyses.**



Part 4: Detailed Protocols

In this section we define a set of experimental questions and indicators for the smaller-scale watershed activities. We lay out framing/guiding questions, more specific experimental questions, and hypotheses. We then use a series of form look-up tables which are referenced in the text and appended to the end of the document before the appendices. Page numbers and table numbers will be references. These tables highlight some of the major indicators ideally tracked to ensure activities are effective. The indicators are general enough to be used beyond just water funds. If similar biodiversity, hydrologic, or socioeconomic goals exist in other projects, the look up tables will be useful to standardize a set of indicators.

In Appendix B, we supply more detailed information with some sample detailed protocols and equipment types that can be used. We put these in an appendix because available equipment and exact protocols are best decided by local experts and those doing the monitoring. We aim for this section to serve as guidance for indicator identification. In each table we highlight some disadvantages and advantages of possible equipment and describe the types of expertise required to collect and analyze the data.

SECTION A: Hydrology

Given the scale and location of these measures in the case of water funds our generalized tables for hydrology measures are geared towards community based sampling techniques, where possible. Such approaches are less costly. In Part 2, we recommended use of more mechanized/automated equipment for the paired watershed design. These types of measures and equipment would be equally applicable in the smaller-scale monitoring and measures, but tend to be more costly and require greater technology for data download. Tables 1a-c provide information about less costly, more community-based sampling methods for monitoring important hydrologic indicators. See Appendix B "Hydrology" for more detailed information about websites for acquiring equipment and other potentially helpful information.

Framing Experimental Question:
How does land cover and land use affect water flow regime, quantity, and quality?

Strategy Effectiveness Measure Questions/Counterfactuals:
Does the water fund work provide benefits in terms of water quantity, quality, and water flow regulation?

1) Does natural ecosystem conservation bring benefits for water flow regulation and water quality?
2) Does implementing BMPs on landscapes bring benefits for water flow regulation and quality?

Hypothesis: Water fund work investments will:

1) **regulate** seasonal **flow** patterns
2) **decrease** or at least **not increase sedimentatio**n levels
3) **improve** or **maintain water quality** levels

<u>Water Quality</u>

Question: What is the impact of improved management practices in productive systems and conservation of natural systems on water quality?
Indicators: Fecal coliforms, dissolved oxygen, pH, temperature, sediment load (and perhaps nutrients such as nitrogen and phosphorus, though these are only an issue in a few existing sites).

Hydrologic indicators, in general, can be measured in a variety of ways from sampling techniques that require little expertise and upkeep and could be done by communities living in the watershed to more mechanized, automated measures. In Tables 1a we highlight various methods articulating some of the advantages and disadvantages of each approach.

<u>Water Quantity and Flow</u>
Question: How do water fund strategies, particularly conservation of native ecosystems, affect timing and volume of water flow regime?
Indicators: Volume and timing of flow

As with water quality indicators, water quantity and flow indicators can be measured in a variety of ways ranging from highlight mechanized and automated to a much more basic and inexpensive approach (Table 1b).

Automated equipment carries the benefit of being more accurate and being continuous in its measures allowing for a better assessment of impacts to key indicators since data is collected much more frequently. Storms and weather events have major impacts on hydrologic indicators and it is critical to capture these events which is much more readily done through automated sampling.

<u>Confounding Variables</u>
Various factors can influence the indicators described for water quality and water flow/quantity. Thus, it is critical to measure these confounding factors – such as precipitation and temperature – to ensure that the results we do or do not see are a result of the water fund interventions and not some broader atmospheric or meteorological condition. See Table1c for a summary of these factors and some basic suggestions for their measurement.

SECTION B: Terrestrial and Freshwater Biodiversity

In this section we jointly address questions and hypotheses associated with measuring the impact of water funds on terrestrial and freshwater biodiversity. The actions and activities so far supported by the water funds to protect natural ecosystems and restore working landscapes jointly impact both terrestrial and freshwater ecosystems. In addition, the indicators we propose as important for these measurements overlap where identical methodologies can be used to measure the integrity of the protected area systems as well as the riparian vegetation restoration in the working landscapes. We highlight where the indicators differ as some will require more or different monitoring techniques, but the transects used to monitor these indicators can be the same. For example, both freshwater and terrestrial indicators can be measured by the same transects that span the length of terrestrial restoration or protection and the streams around which it occurs (see Figure 9 Sample point 4 - a transect could run from one fence to the fence on the other side). The selected indicators detailed in this section both for freshwater and terrestrial biodiversity are used to measure the integrity of those systems (described in more detail below).

Framing Question: Do water fund investments impact the integrity of terrestrial and freshwater ecosystems?

Framing Experimental Questions

1) How does hiring of park guards affect the conservation of protected areas and the water ways within them?
2) How does taking cattle out of the forests and páramo affect terrestrial and freshwater biodiversity?
3) How do water fund strategies in productive landscapes affect freshwater and terrestrial ecosystem integrity and thereby associated biodiversity?

Strategy Effectiveness Measure Questions

1) Does the water fund work provide benefits to the integrity of the freshwater and terrestrial ecosystems?
2) Are key freshwater and terrestrial ecosystem attributes affected by watershed degradation and are water fund interventions improving their condition?

Hypothesis: Conserving natural ecosystems, implementing best management practices on the rural, working landscapes such as fencing off waterways, fencing headwaters, re-vegetating and re-foresting the landscape, and decreasing the amount of cattle on the landscape while preventing further degradation of the protected area will:

1) **Enhance or maintain** ecosystem integrity (terrestrial and freshwater)
2) **Result in more natural composition** and **density** of vegetation, insects, and macroinvertebrates

Terrestrial biodiversity indicators

Terrestrial biodiversity indicators:

1) Deforestation – satellite imagery to measure rate of deforestation (see Table 2a)
2) Insects – relative abundance, community composition, and morphology (see Table 2b)
3) Plants/Vegetation – understory plant abundance and morphology (see Table 2c)

Freshwater biodiversity indicators

Some of the indicators here will not be freshwater targets but more indicators that give a sense of the integrity of the system (see table 2d).

1) Macroinvertebrates – Composition, relative abundance, and overall abundance – composition being a more important measure than abundance since the presence of particular sensitive taxa are good indicators of specific water quality attributes. For instance, caddis fly larvae that spin nets to capture their prey require low sediment levels to be successful. Macroinvertebrate communities dominated by tubificid worms can indicate poor water quality from high bacterial and low oxygen levels.
2) Geomorphology – indicators of the composition and condition of in-stream habitats, such as riffles, pools, runs.
3) In stream habitat structure – indicates the geomorphic stability of the stream channels measuring stability or instability of the stream bank itself.
4) Riparian vegetation/Vegetation – this indicator is equivalent to the plant/vegetation indicator (see Table 2c) described in the terrestrial biodiversity section.

Justification for Freshwater proxy: Marcoinvertebrate, particularly the presence and abundance of sensitive species, are good indicators to monitor and measure improvements in the freshwater system's health.

In stream habitat structure can be measured using stream visual assessment protocol (SVAP) and/or Bank Erosion Hazardous Index (BEHI). Both will assess the geomorphic stability of the stream channels, which are a crucial component of establishing the initial condition. If ht stream channel is unbalanced and unstable this will impact sediment load.. Invariably under these conditions there will be significant bank erosion and head-cuts, which will not be accounted in any GIS model, and will mask the sediment abatement benefit from watershed protection/restoration. Assessing in-stream processes should be part of the initial baseline for each site.

Justification for Terrestrial proxy

There are multiple considerations for terrestrial biodiversity. The main goal for the terrestrial systems is the conservation of intact landscapes and improvement of managed ones. For ecosystem conservation this involves both ensuring that deforestation is no longer occurring but also that removal of cattle from the areas and other preventative measures are in fact improving or at least maintaining the conservation value of the systems. On the working landscape, it means ensuring that restoration (passive or active) is enhancing on-farm biodiversity. In collaboration with other TNC efforts, namely led by Stephan Halloy in the Southern Andes, we propose using an index that would demonstrate the integrity of the terrestrial system by understanding how the current pattern of indicator abundance and other morphological features varies from "normal."

Halloy and Barratt (2007) researched the validity of this approach and in conversation with Halloy, we think this model is worth considering for measuring the impact on terrestrial biodiversity of water fund investments, namely effectiveness of park guards and best management practices on improving biological integrity (see Halloy, S. and Barratt, B. 2007. Patterns of abundance and morphology as indicators of ecosystem status: A meta-analysis. *Ecological Complexity* 4: 128-147). The basic conclusions reached were that various features of organisms can be used to assess whether or not a system is disturbed based on pattern analysis. These features can include abundance (number of individuals, cover, biomass), number of species per taxon, and morphological features (individual weights, volume, body lengths, leaf areas, etc). For this type of analysis, the most effective features of organisms to use are those related to competition for resources. Plant and insects tend to have greater discriminating power than other groups for this type of disturbance measures. Measuring plant and insect features provide a universal, consistent, and effective way to collect information that will lead to a basic understanding of the degree to which a system is disturbed from its "natural" features.

Halloy and Barratt (2007) developed an analysis methodology for measuring the degree of departure of a community from the lognormal. Measuring the abundance or morphology of a plant or insect community, for example, and analyzing the departure of current patterns from predicted lognormal patterns is a means to measure the impact of biological conservation approaches on diminishing a disturbance to the system. If the measured pattern is lognormal or close to it, then likely the community or ecosystem is dominated by internal interactions and likely is undisturbed or "healthy." Thus measuring the distance from the predicted lognormal (ΔL) is a reliable indicator of disturbance or conversely of biological integrity. The accuracy of this measure depends on sound sampling methods and statistical analysis and on sampling representative taxa including measuring parameters sensitive to competition.

Thus, in the water fund cases we propose using at least plant abundance and, ideally, insect abundance as a way to develop an index to know the variation from the lognormal predictions. In the paramo and forest (this would also work for the stream macroinvertebrates and for the riparian vegetation), this would include e evaluating plant cover and leaf area (or body volume for insects) of the species present. The exact sampling methodology and the number of sites in the controls, counterfactuals, and treatments must be determined in conversation with local experts.

Confounding variables: As with hydrologic measures the indicators associated with biodiversity measures have some confounding factors that might influence the results we see in our indicator measures. The major confounding variable would be erosion. While potentially captured through turbidity measures (see Hydrologic indicator section) it is best to measure the land-based erosion directly – see Table 2e for a relatively inexpensive and straightforward methodology for so doing.

SECTION C: Socioeconomic Indicators

Water funds currently use a variety of alternative livelihood/resource strategies to mitigate against impacts to communities' well-being. Because water funds often require that communities remove cattle and crops from the páramo and forest regions and implement best management practices on their land, these communities can suffer losses in productivity, at least in the short run. (In the long run, however, some of these changes may enhance the productivity of the landscape). Strategies used by water funds to compensate for these losses include providing seeds, training, and resources for backyard organic gardens; resources, training, etc. for other jobs such a sewing; capital for guinea pig farms; and other efforts. Socioeconomic indicators would require a control where similar sets of interviews are conducted with families that are not participating in water fund projects. These groups should be in neighboring subwatersheds where families rely on the same sets of income sources and resources (see Figure 9 point 3 or 3a depending on the size of the basin).

Question: Are strategies implemented by the water fund as alternative strategies enough to compensate for any loss to human well-being?

Indicators:

1) Participation
    a. Through time, how many families that started participating in the water fund projects continue to do so? (Longevity)
    b. Through time, how many more families start participating in the fund? (Attract new people)
2) Net Income – interviews that ask indirect questions about sources of income and expenditures to ensure that over time these things at least balance even if sources change.

Participation indicators can be tracked as performance measures through time. In theory, if participation continues to increase then one might be able to assume that the projects are at least doing no harm or families would not continue to join and/or continue to participate through time. Thus, measures of longevity of participation and new families joining the water fund projects can be used as a very rough proxy for well-being at least being maintained or improved.

Thinking more about economics directly, water fund compensation projects should *at least* compensate families for any impact to their income from implementing best management practices on their working landscapes. For example, fencing off headwaters and waterways will reduce the size of available land for grazing. As a consequence fewer cows can be supported on the landscape and likely milk production will diminish which means the family will have less milk to sell. Any compensation project – be it an organic garden or a guinea pig farm or a sewing machine – must at least save the family as much money or make the family as much money as they lose in income from milk selling. This net income balance will be a direct measure of potential added benefits of water fund towards increasing a families' net income (see Table 3a).

These economic measures do *not* measure other potential benefits associated with water funds' work with communities. Water funds have an important environmental education component worth consideration and the impact such education has on the people. In addition, organic gardens provide a more secure nutrition source for families and the water fund projects should also provide a cleaner water source which might help with disease incidence. Income diversification through the compensation projects can have significant benefits for alleviating poverty. Finally, there may be numerous cultural impacts from water fund investments and benefits for women and other more social factors that would be worth measuring. If possible, developing measures to demonstrate these other possible impacts would be ideal.

Another potential methodology for measuring socioeconomic impacts from water funds is to use a similar protocol to that being used by TNC's poverty initiative. This initiative led by Sanjayan and Craig Leisher uses a World Bank methodology assessing projects post hoc using a variety of methods: workshops, surveys, interview, etc. SeeTable 3b for a summary of the indicators and basic methods that are used in this assessment that might prove effective for water fund measures as well.

SECTION D: Other Indicators

As mentioned in discussion of Figure 1, it is important for all impact measures to link back to the functioning of the financial and institutional mechanism. A key part of a functioning institutional mechanism is if the partnership can interpret data and results from measuring impact and adjust and adapt water fund goals, priorities, strategies, etc accordingly. Apart from this, a basic set of impact measures can be developed for these mechanisms as well.

Governance/Institutional mechanism

1) Institutional strengthening
2) Adaptive decision-making
3) Ensuring all voices heard

One proposal for how to advance a set of indicators that can measure the effectiveness of the water fund institutional structure is to use some of the basic indicators developed for the Parks in Peril program. When TNC worked on the Parks in Peril project funded by USAID they developed a scorecard methodology for evaluating the effectiveness in achieving an objective. The scorecard was based on a 1-5 scale where 5 was successful completion of the objective. A number of the different categories could relate to water fund monitoring but are geared more towards activity or process measures rather than impact. However, some of the management measures could be applied to water funds as an initial way to assess the governance structure.

For example several indicators that would demonstrate that the public-private partnership is effective in managing the water fund would include:

1) Everyone gets and uses their vote;
2) A monitoring plan is developed, implemented, and results are used for decision making;
3) The institutional mechanism works with other important stakeholders and can impact decisions (such as the national ministry of environment); and
4) Communities are involved in decision-making as appropriate.

The Parks in Peril program created a scale of 1-5 for some of these indicators with appropriate benchmarks for advancing from a 1 to a 5. For example, with a monitoring plan, according to Parks in Peril monitoring plans should propose appropriate indicators to measure the decline of threats to the area and that is cost effective. The monitoring scorecard refers to data that is then collected and used to assess changes over time. For example, a water fund would receive a level of 2 when information is being gathered (no analysis) and no assessment has been done of its use towards measuring a threat decrease. A score of 3 is achieved when the data has been analyzed and determined what is relevant. A score of 4 means the data are being collected based on an experimental design and both socio-economic and biological indicators are measured. Finally, a 5 means the data and analyses are being used in decision making.

One key water fund goal is to help manage protected areas. Thus, the governance committee needs to be involved in decisions that influence the national ministries of environment. Here, the parks in peril scorecard could again be useful since representation and participation are important components of the water fund governance structure. A functioning governance committee (score of 4) is both representative of key stakeholders but also participatory in key processes. Water funds are slightly different than Parks in Peril but the metric of ensuring that the governance structure is not operating in isolation but rather works with other appropriate government and non-government stakeholders is important. Participation could be measured by instances of committee members or the water fund technical secretariat being consulted on management plans, operating plan, spending plans, etc of other watershed stakeholders. More active participation (score of 5, for example) might include actually helping design management plans such as by the ministry of environment or a more official interaction. Such measures could also be made broader where the water fund institutional mechanism gains more prominence as a valid and valuable watershed player.

Finally, community involvement in decision-making is a way to measure governance effectiveness. Formalizing the participation of community groups and other important watershed stakeholders in decision-making can be very important and for water funds this may mean "official" board membership. Benchmarks and scores for this indicator could include differing levels of engagement and documentation that could allow the mechanism to be replicated. For example, a score of 3 might be achieved when communities are engaged in pilot projects and results are documented. A score of 4 would means engaging communities or civic groups on broader regional projects, and a 5 might mean involving the major regional organizations and/or associations present. This may or may not be applicable in a water fund but assessing on some level the mechanism by which communities are engaged could be a measure of the governance effectiveness.

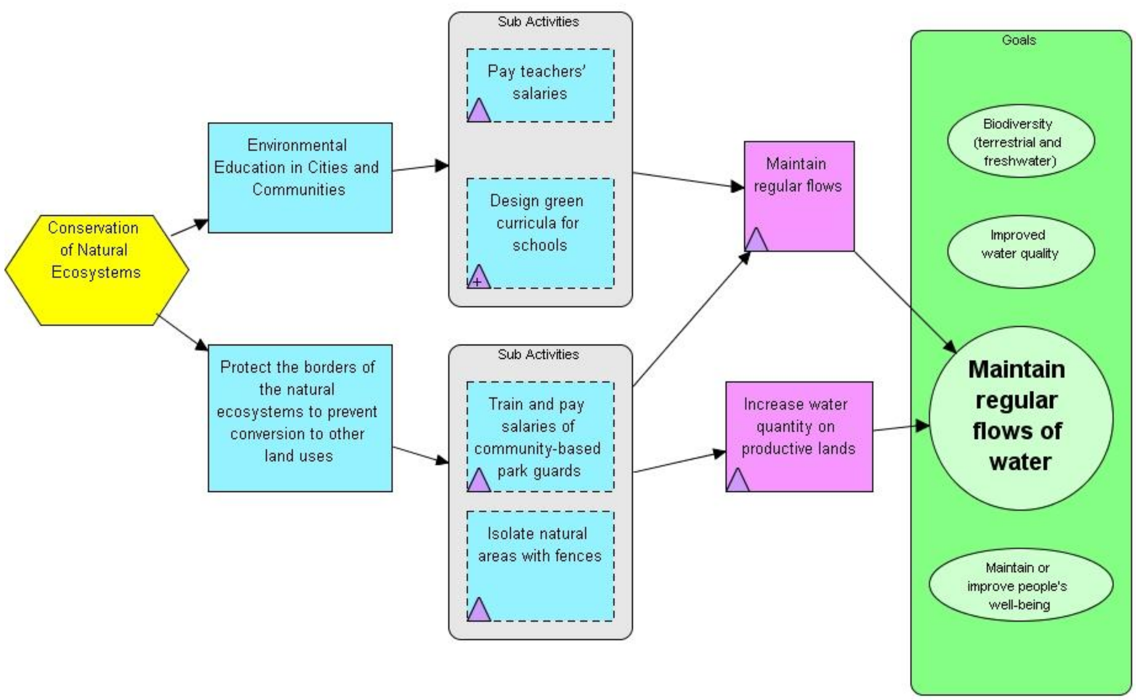
Financial mechanisms – TBD

1) Yearly financial flows
2) Increasing budget

APPENDIX A

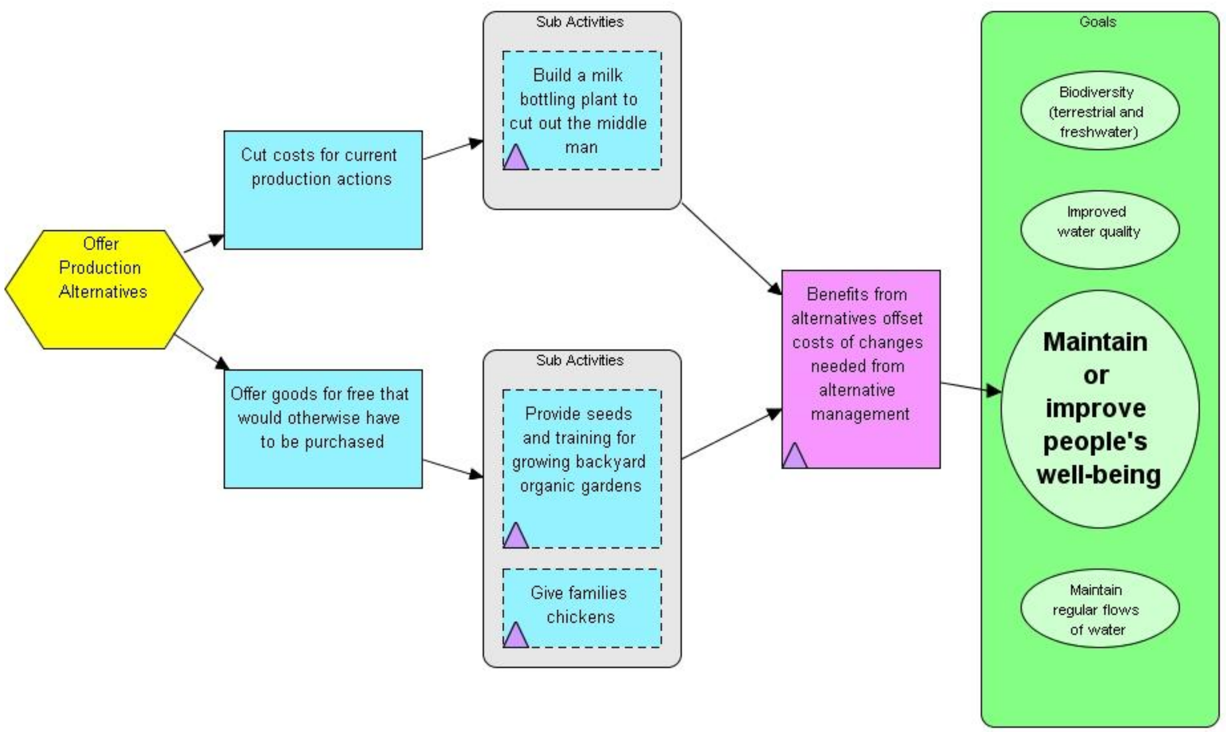
Goal: Maintain Regular Flows of Water

Strategy	Activity	Activity			Impact	
		Sub-Activity	Indicator			
			Process	Threat reduction	Desired impact	Impact Indicator
Conservation of Natural Ecosystems	Environmental education in community and city schools	Pay teachers' salaries or design green curricula for schools	Number of additional teachers, number of schools with green curricula	Number of families who don't convert natural areas on their lands	Natural ecosystems help regulate and maintain water flows	Volume and timing of flow
	Protect the borders of the natural ecosystems to prevent conversion to other land uses	Train and pay salaries of community-based park guards	Number of park guards	Number of hectares of natural ecosystems not converted	Maintain regular flows of water diminishing the numbers and strength of floods and droughts	
		Isolate natural areas with fences	Number of isolated areas		Increase water quantity on the land	



Goal: Maintain or Improve People's Well-being

Strategy	Activity	Activity			Impact	
		Sub-Activity	Indicator			
			Process	Threat reduction	Desired impact	Impact Indicator
Offer Production Alternatives	Cut costs for current production actions	Build a milk bottling plant to cut out the middle man	Number of villages with a bottling plant	Number of fewer cows now on the lands	People's well being in the communities in maintained or improved	Cost reduction for production equals opportunity cost of fewer cows
	Offer goods for free that would otherwise have to be purchased	Provide seeds and training for growing backyard organic gardens	Number of gardens			Income flows are balanced
		Give families chickens	Number of families with chickens			



APPENDIX B

Hydrology

Different methodologies are being discussed for these indicators. In one water fund we are going to propose community sampling techniques where the landowners in the watershed actually do the measurements. These methodologies will be fairly cheap, basic and hopefully straightforward. Lab work will be needed. In another water fund we are going to propose a more comprehensive measurement largely managed by academics and the main water utility. The equipment for these will be more expensive but will also, hopefully, be continuous to really be able to measure impacts during flood events. Meteorological towers will be needed in both cases to measure winds, precipitation, etc to be able to have good controls.

There are a number of options to consider when purchase water monitoring equipment. Major companies that specialize in such equipment include:

1) Ben Meadows: http://www.benmeadows.com/
2) ISCO: http://www.isco.com/

The types of equipment to order vary depending on the selected indicators. Measuring fecal coliforms is slightly more complex than other water quality and quantity indicators. Thus, costs are likely to be higher if these indicators need to be measured.

[Status]

Some suggestions for equipment for different indicators are as follows:

- *Discharge and streamflow rate*: It is very important to choose the right equipment for the right stream.
    - Small streams could be equipped with flumes with water level recorders and large stream will be equipped with ISCO Area-Velocity probe mounted on a Culvert which will cost around USD 4,000-5,000.
    - A second option which requires more person labor would be installing some type of stilling well with a water level recording device, such as the Solinst levelogger or the Hobo data logger in addition to measuring water velocity in the stream and establishing a stage-discharge relationship.
- *Physical parameters*:
    - For sediment monitoring, there is a good proxy associated with measuring turbidity. Turbidity, temperature, pH, conductivity and Dissolved Oxygen could be monitored using grab samples and YSI/Psonde device. The more grab samples the better the information will be. Timing and frequency of samples depend on the flashiness of the weather patterns in the area.
    - There are other tools and equipments for continuous automatic monitoring but they are a bit expensive, but there are options for these types of equipments too
- *Biological parameters:* Fecal Coliform and all other biological parameters are highly variable in space and time. Continuous monitoring would not work well as any delay in testing the water sample could negatively change the data. So grab sampling is the best option to monitor Fecal coliform and again time and frequency are crucial and should be selected based on sampling locations.

Freshwater Biodiversity

Potential Methodology for measuring freshwater indicators

The exact details of this methodology will really depend on the state of the watersheds in question since methods for macroinvertebrate sampling depends upon stream habitat – i.e. riffles versus pools.

The macroinvertebrate sampling will be particularly important in the landscape as this is where the major sedimentation and water quality problems are. The native ecosystems are relatively well conserved particularly compared to the productive land uses. Ideally, we would monitor macroinvertebrates in the natural ecosystems too.

This is an abbreviated methodology which we can work on after learning more about the Andean systems at the workshop. Basically streams have three types of "habitats":

1) Riffles – created where water flows through rocks or coarse substrates and are generally areas of high oxygen where particularly sensitive macroinvertebrate species can live
2) Pools – these are slow flowing areas of the stream where the depth is a little greater than in other parts of the stream
3) Run – the rest of the area of the stream where water flows without being intercepted by major rocks or areas of greater depth

Sampling for macroinvertebrates ideally will be done in the riffles of the stream as this is where sensitive taxa gather. If a stream does not have a lot of riffles, then core sampling techniques would be needed for macroinvertebrate sampling.

We will need both a core sampler and a Surber sampler (appropriate for riffle measurements) so that we have the ability to test both types of habitats within the stream reaches. It's particularly important to measure both along a reach if one of the effects of land use in the watersheds has been sedimentation since sediments can essentially diminish the presence of riffles. Thus, with improved land management, there may be a return of riffles to the stream habitat which in and of itself demonstrates an improvement in ecosystem condition.

In each of our three reaches in our subwatershed, we will sample 3 locations (so 9 locations within the subwatershed total) for macroinvertebrates and for vegetation sampling. If riffles exist in the stream beds, then transects for riparian vegetation will be stretched across the area perpendicular to water flow. Sites within a reach to do macroinvertebrate sampling will be randomly selected based on riffle presence.

Within 100 meter reach we will take a total of 3 samples. At each sample:

1) Find a riffle near the end of the reaches (look for big rocks)
2) Sample macroinvertebrates in riffle using Surber sampler
3) Sample macroinvertebrates in any pools in the same general vicinity
4) Walk upstream 20-30 meters until find another riffle
5) Sample riffle and nearby pool
6) Walk upstream a further 20-30 meters and repeat

Sample this way twice a year depending on seasonality.

We will mark our areas of sample collection so that we can return to the same area to do our vegetation samples each year.

At each riffle site – the vegetation sample will extend from the fence on one side across the stream to the fence on the other side (or the same length transect in the control sites. Along the length of the transect the number and type of plant species will be recorded. In addition, across the stream the general substrate will be noted (rock, pebble, fine-grained sand, etc) based on pre-determined classifications.

One suggestions for vegetation sampling would be to measure every 2 meters using a ½ by ½ meter quadrat to sample richness, abundance, and density of vegetation along the transect.

Data Analysis – Further Details

Macroinvertebrates

Surveys of macroinvertebrates can be done for three main reasons:

1) Biodiversity for sake of measuring biodiversity
2) As indicator
    a. General water quality
    b. Sedimentation
3) As keystone in the food web
    a. Important link in food chain
    b. Losing particular orders can have large cascading effects

To be able to use macroinvertebrates for all of the above, it is important to be as detailed as possible with the processing of the macroinvertebrate samples. There is a lot of lab work in separating the samples and identifying them. In so doing it is important to get measures of:

1) Abundance of different taxonomic groups
2) Richness
3) Diversity
4) Number of each individual in EPT groups*
5) Biomass

*Ephemeroptera, Plecoptera and Trichoptera groups (mayflies, stoneflies and caddisflies) forms a measurement called '%EPT'. Low %EPT indicates a river is under pollution stress, while high %EPT indicates good water quality.

NOTE: Depending on type of analysis, identification to species may not be necessary. Although it is a plus, the cost and feasibility (no specialists may be within easy reach or have time) may be prohibitive. So approaches here tend to be 'parataxonomic', utilizing morphospecies.

Riparian Vegetation and Substrates

At each point of macroinvertebrate sampling we will lay out a transect perpendicular to water flow. The transects will be about 15 meters or so in length given that fences are usually 5 meters from the water's edge on either side. These transects are indicated by the black bars between the fencing on the cartoon on the previous page. At each 1/10 of a meter we will take the following measurements:

1) Substrate information: cobble, boulder, sediment, etc
2) Riparian vegetation
    a. Yes/No plant touching the transect
    b. If yes, species will be identified

Measures of geomorphology/substrate would be done along the same transects as riparian vegetation.

Indicator Look-Up Tables

Tables 1a-c Hydrology: Water Quality and Water Flow

Table 1a: Water Quality

<table>
<tr><th rowspan="2">Goal or Objective</th><th rowspan="2">Indicator</th><th rowspan="2">Confounding factors</th><th rowspan="2">Methods in Brief</th><th rowspan="2">Frequency of Measurement</th><th colspan="2">Necessities for Collection</th><th rowspan="2">Data Analysis Requirements</th><th rowspan="2">Comments: Advantages, Disadvantages, Hurdles</th></tr>
<tr><th>Equipment (examples)</th><th>Personnel</th></tr>
<tr><td rowspan="4">Maintain or Improve water quality</td><td rowspan="2">Sedimentation-Nutrients: Reduction in Turbity</td><td rowspan="2">part size dist, Dissolved Oxygen, pH, flow</td><td>turbidity tube</td><td rowspan="2">after storms, before major planting and seeding, after harvest, biweekly in between.</td><td>Turbidity Tube and associated equipment</td><td rowspan="4">Anyone could do this as long as they are trained properly and are trustworthy to take the time to do the tests correctly.</td><td rowspan="2">Understanding of relationship between turbidity, DO and flow. Hydrology expertise required for full data impact analysis.</td><td rowspan="2">Turbidity includes a lumped value of organic and unorganic matters, so it is difficult to disassociate sediment from organic matters and nutrients.</td></tr>
<tr><td>portable turbidimenter, portable probe</td><td>Portable turbidimeter, portable probe</td></tr>
<tr><td rowspan="2">Fecal Coliforms: Reduction in bacteria concentration</td><td rowspan="2">water temp, flow, dissolved oxygen</td><td>coliscan easy gel</td><td rowspan="2">after storms, especially after spring summer hot and wet season, biweekly in between.</td><td>Coliscan easy gel is inexpensive and gives some reliable results.</td><td rowspan="2">Need to understand the meaning of the coloring and record the results properly. No special analysis beyond this is necessary.</td><td rowspan="2">Timing is very important factor in FC monitoring! Important to monitor after big storms and after spring (hot-wet) storms.</td></tr>
<tr><td>traditional coliscan test</td><td>Kit will have all needed equipment</td></tr>
</table>

Table 1b: Flow regime/Water Quantity

Goal or Objective	Indicator	Confounding factors	Methods in Brief	Frequency of Measurement	Necessities for Collection		Data Analysis Requirements	Comments: Advantages, Disadvantages, Hurdles
					Equipment (examples)	Personnel		
Improve or maintain regular supply of water	Volume and timing of flow is more regular and continuous streamflow is maintained.	precipitation, soil moisture, air temp, humidity, wind speed	manual x-sections & simple velocity measure	Measure as regularly as possible, depending on hydrologic regime, as well as capturing extreme low flows and high flows right after a storm. Warning: manual velocity measurements can be dangerous during high flows.	Velocity - flow meter or manual measurement with a ping pong ball or stick and a stop watch. Cross section - tape measure and measuring stick (or long stick marked off)	one time training-periodic site visits.	Can use a standard form to fill in the results that makes the analysis really easy. As with all the other data collected, need to make sure the community collectors are keeping track of the data in a way that will be easy for later analysis. Hydrologic expertise required for full data analysis. Full complete rainfall-runoff analysis based on the monitoring frequency.	Most appropriate for small streams as larger streams may be dangerous to wade in and will be time consuming to measure. May miss out on capturing the full range of high and low flows, and the timing of runoff vs flow, but this method is very inexpensive.
			manual-automatic water level readings		Build a weir to get the proper water depth - discharge relationship, or establish it periodically, and mark off water depths that can be read easily from the banks of the stream.			Less dangerous and likely more accurate than in stream flow measurements for high flows. Higher initial cost than manual flow measurements, but easier to read. Again, may miss our on capturing the ful range of high and low flows, and the timing of runoff vs flow, but this method is less expensive than automatic equipment.
			automatic equipment that requires calibration but then calculates volume and timing automatically.	Continuous	Most cost effective mechanized equipment		The data logger should save data in a format that is easy to perform analysis on, such as Excel worksheets. Hydrologic expertise required for data analysis.	Requires calibration. Continuous readings can be well worth the cost of the equipment.

Table 1c: Confounding Variables

Goal or Objective	Counfounding Variable	Possible Methods/Equipment	Frequency of Measurement	Personnel
Measuring confounding factors	Particle size distribution	lab method	whenever water quality and water flow sampling happens	some expertise helps but anyone could be trained to collect this data
	Water temperature	portable		
	Dissolved oxygen	portable		
	Precipitation	rain gage		
	Soil moisture	Field-lab method		
	Air temperature	Thermometer		

Table 2a-e: Biodiversity: Freshwater and Terrestrial Ecosystem Integrity Indicators

Table 2a: Avoided Deforestation

Goal or Objective	Indicator	Methods in Brief	Frequency of Measurement	Necessities for Collection		Data Analysis Requirements	Comments: Advantages, Disadvantages, Hurdles
				Equipment (examples)	Personnel		
Maintain and enhance integrity of the terrestrial natural ecosystems	**Avoided Deforestation**: 1) No receding of forest boundary 2) Forest cover increases on the landscape	• Terra-i for early warning • Satellite imagery for baseline and periodic check	Annual	Computer with ESRI GIS software	Spatial analyst trained in use of Terra-I data	Updated Terra-I data set - can use annual data or more frequently if desired (new data sets available every 16 days)	**Advantage**: Provides regularly updated information on habitat conversion at a fairly fine scale (resolution = 6.5 ha). **Disadvantage**: Satellite imagery and tracking forest cover does not reveal health of ecosystem per say since cattle often destroy the understory. But relatively quick and inexpensive monitoring.

Table 2b: Insects

Goal or Objective	Indicator	Methods in Brief	Frequency of Measurement	Necessities for Collection		Data Analysis Requirements	Comments: Advantages, Disadvantages, Hurdles
				Equipment (examples)	Personnel		
Maintain and enhance integrity of the terrestrial natural ecosystems	**Insects**: 1) Higher relative abundance distribution, (or frequency distribution), and community composition (indicator, native, exotic spp) 2) Greater diversity of morphological traits specifically functional traits, trophic groups or guilds for example	Measure insect abundance and body volume along a transect. Exact methods to be determined with local experts	At least dry season and wet season but to be determined with local experts, ideally, link spatially and temporally to the satellite image (terra-i) analysis	usual insect collecting: net, pitfall traps, berlese separator, volume measures, GPS, magnifying, literature	parataxonomist with field assistance. Access to entomologist for support	basic statistical analysis, excel and/or simple statistical software	**Adv**: insects, particularly large speciose groups like Coleoptera, have been widely studied and used as indicators, so there is a lot of information on their sensitivity and reaction to disturbance. Field work relatively straightforward given training. **Dis**: requires a minimum level of training and establishment of agreements with some local research group. Park guards and local people can do some of the local collecting, but need to be trained. Then supply the samples to researchers who can sort morphospecies and do analyses.

Table 2c: Vegetation/Plants

Goal or Objective	Indicator	Methods in Brief	Frequency of Measurement	Necessities for Collection		Data Analysis Requirements	Comments: Advantages, Disadvantages, Hurdles
				Equipment (examples)	Personnel		
Maintain and enhance integrity of the terrestrial natural ecosystems	**Plants/Vegetation**: Higher abundance and greater diversity of morphological traits of plants	Measure plant cover and leaf area using quadrats (and/or point intercepts) along a transect. Exact methods to be determined with local experts.	At least dry season and wet season but to be determined with local experts, ideally, link spatially and temporally to the satellite image (terra-i) analysis	tape measure, string, stakes, premade cuadrats, GPS, key to plants, leaf area measure	parataxonomist with field assistance. Access to botanist for support	basic statistical analysis, excel and/or simple statistical software	**Adv**: plants are the base trophic level, highly responsive to environmental conditions (both biological and physical), and have been widely studied and used as indicators, so there is a lot of information on their sensitivity and reaction to disturbance. Field work relatively straightforward given training. Most managers/rangers know local plants fairly well or can be easily trained. Plants form the basis of what is captured by satellite imagery, so measures of cover and structure are essential ground-truthing for the larger scale measures. **Dis**: requires a minimum level of training and establishment of agreements with some local research group. Park guards and local people can do some of the local measuring, but need to be trained and information followed up and verified by researchers who can sort morphospecies and do analyses.

Table 2d: Macroinvertebrates and Geomorphology and In-Stream Structure (please contact Paulo Petry for In-Stream Structure)

Goal or Objective	Indicator	Methods in Brief	Frequency of Measurement	Necessities for Collection		Data Analysis Requirements	Comments: Advantages, Disadvantages, Hurdles
				Equipment (examples)	Personnel		
Maintain Integrity of the Freshwater System	**Macroinvertebrates**: 1) Presence of sensitive species 2) High %EPT species 3) Greater overall richness of family type 4) Higher abundance in particular families 5) Higher biomass	• Sample Riffles, if available, but also in some pools. • Can use equipment or simply kick sampling.	Depends on seasonality but usually dry season and wet season measurement	Suber samplers for riffles, Core samplers for pools, or kick sampling	One person with basic training on methods	• Laboratory with microscopes • Expert to ID species • Computer and database to compile information • Tech person to analyze and interpret	*Richness* data can tell you a lot about water quality and sedimentation but takes a LOT of detailed expertise for ID *Abundance* is cheaper and easier to collect particularly using kick sampling but not as sensitive an indicator
	Geomorphology: Diversity of substrate types on river bottom	Transect across waterway sampling at defined intervals as apporpriate for the size of the waterways		Tape measure, waders, rain proof notebook	No technical expertise needed	Computer and spreadsheet for analysis	
	In -stream habitat structure: Greater stability of the stream channel and bank	Use either: stream visual assessment protocol (SVAP) and/or Bank Erosion Hazardous Index (BEHI).					

Table 2e: Confounding variables associated with terrestrial and freshwater indicators

Goal or Objective	Counfounding Variable	Possible Methods	Frequency of Measurement	Necessities for Collection: Equipment (examples)	Necessities for Collection: Personnel	Data Analysis Requirements	Comments: Advantages, Disadvantages, Hurdles
Measuring confounding factors	Soil erosion	Establish site on a slope and build a a metal buffer about 10 meters on each side shaped into a v-shape. The metal buffer should be buried into the ground. At the base should be a collector to collect water flowing over the ground. The water in the collector can then be filtered out and the sediment weighed.	Collect and weigh the sediment every time it rains	Metal buffer can be made of any metal lining that can be purchased cheaply at a hardware store and collectors can be any plastic container.	Very basic training needed for collection and keeping track of data.	Data should be analyzed along with other terrestrial indicators.	This is a very inexpensive methodology with readily available materials.
	Preciptation	rain gage	Everytime erosion measured	Can be purchased cheaply			

Table 3a,b: Socioeconomic Indicator tables

Table 3a: Economic indicators of income change

Goal or Objective	Indicator	Methods in Brief	Frequency of Measurement	Necessities for Collection: Equipment (examples)	Necessities for Collection: Personnel	Data Analysis Requirements	Comments: Advantages, Disadvantages, Hurdles
Maintain or enhance human well-being	Net income greater or maintained	Interviews of families to determine cash flow - what spend money on, how earn money, biomass of sold products, etc.	Annually or biannually or whenever feasible	Interview protocol, means to record results (notebook or tape recorder)	Basic socioeconomic expertise for interview design. Preferably trusted community member to conduct interviews.	Statistical analyses and qualitative assessment expertise.	More of an economic measure to ensure that livelihood compensation projects are adequate or more than adequate to cover project opportunity costs, but does not measure health impacts, cultural impacts, gender impacts, etc

Table 3b: Social and Economic indicators based on World Bank methodology

Goal or Objective	Indicator	Methods in Brief	Frequency of Measurement	Necessities for Collection		Data Analysis Requirements	Comments: Advantages, Disadvantages, Hurdles
				Equipment (examples)	Personnel		
Maintain or Improve People's Well-being	**Opportunities**: 1) Income, housing, education and acquisition of luxury goods increase compared to the control sites 2) Natural Resource Use reduced 3) Share of non-farming income increases 4) Share of non-farming expenses decrease	Triangulation technique • Household surveys • Focus Group Discussions and key imformant interviews • Semi-structured interviews	Initial survey after first year and then every three years afterward. Eventually turn survey over to the community group.	Clipboards, Multiple survey copies, pens Computers for data analysis, can be conducted off-site	Multiple people, fluent in the local language and familiar with surveys; Skilled facilitators needed to collect qualitative data	• Expert Statistician needed to design the survey • Facilitators to conduct the discussions and key informant interviews • Field reps to conduct the survey, potentially need to be bilingual • Computer and database to compile information • Statisitician to analyze and interpret data	Statistically significant quantitative surveys take significant planning and effort to carry out. All surveys require post-completion analysis. Additional teachers needed or additional training needed. Additional training or recruitment of bilingual facilitators needed.
	Empowerment: 1) Number of villagers participating in governance increases 2) Villagers feel they can impact change 3) Transparency and communication increase 4) Changes in the roles of women and men						Additional thought on how to structure community based governance on such a program is needed to address this area How are cooperatives initiated and maintained?
	Security: 1) Is there increased access to healthcare? 2) Are participants' diets healthier? 3) Other community groups established? 4) Is coordination amongst farmers improved? 5) Are cooperatives seen as a benefit?						How do we measure commitment and ensure that the metrics do not encourage short term gains to the detriment of long-term sustainability?