Science-based investment targeting for the Water for Life and Sustainability Fund, Colombia

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1. Background

The water funds concept has been gaining increasing traction throughout Latin America in the last decade as a flexible and sustainable mechanism for long-term investment in watershed conservation and restoration. Through targeting key upstream ecosystems, water funds aim to achieve multiple benefits, including improving or maintaining water quality and regulation of water flows downstream. Since the launching of the first water fund (FONAG in Quito, Ecuador) in 2000, the approach has grown rapidly through the Latin American region. This growth has been bolstered by the Latin American Water Funds Partnership\textsuperscript{1}, a regional partnership which provides support to 17 operational water funds and aims to establish 32 new water funds in the continent by 2016. Building on the success of the Latin American experience, the water funds concept is now being expanded to the United States and Africa.

This growing interest has spurred a need to build and make available tools, guidance and case studies that can allow the water funds model to be adapted to and replicated in various geographic, socio-political, and hydro-climatic contexts throughout the world. The Natural Capital Project and The Nature Conservancy (TNC) have partnered in the development (RIOS) and application of ecosystem services tools (RIOS and InVEST) for water funds design, as well as in the establishment of monitoring programs that will measure the impact of water funds on hydrologic and socio-economic outcomes.

This case study on the Water for Life and Sustainability Fund in the Cauca Valley of Colombia highlights the use of Natural Capital Project tools in water funds development, with the objective of sharing experiences and methodologies so the approach may be replicated in and adapted to other water funds.

\textsuperscript{1} The Latin American Water Funds Partnership brings together TNC, the FEMSA Foundation and the Global Environment Facility through the Inter-American Development Bank (IDB).
2. The Water for Life and Sustainability Fund

The Cauca River flows throughout southwest Colombia; the river stretches more than 1,300 kilometers before emptying into the Magdalena River and then into the Caribbean Sea. Among the most fertile valleys in the world, the East Cauca Valley supports some of the most productive sugarcane plantations in Colombia. In fact, the sugarcane industry alone employs tens of thousands of valley residents and is a primary source of income for the area.

The Water for Life and Sustainability fund grew out of a program originally implemented in the Cauca Valley in the 1980s as part of a national watershed management strategy. At that time, large-scale agricultural interests, concerned about the supply of water for their crops, funded the implementation of management plans for sub-watersheds of the Cauca River. By 2002, there were more than 12 grassroots water user associations in the Cauca Valley. Contributing members of the associations – generally the major sugarcane producers in the valley – paid fees according to their water concessions. The fees were used to finance community projects – promoting reforestation, stream protection and environmental education – in order to assure higher flows during dry periods and to stabilize flows during the rainy season. These associations set a precedent for mobilizing private funds for watershed protection.

In 2009, The Nature Conservancy (TNC) signed a legal agreement with ASOCAÑA (Colombia’s primary sugarcane producers’ association and a leader of the original water program), ten water user associations, and several other groups to create a “water fund” for the valley. The new water fund was called Agua por la Vida y la Sostenibilidad (APLV) – Water for Life and Sustainability – and today it encompasses 20 sub-watersheds along the eastern slopes of the Cauca Valley (Figure 1). In addition to sustainable agricultural water supplies, the fund’s objectives include biodiversity conservation and improved living conditions in participating communities.
Figure 1. The 20 sub-watersheds that make up the Agua por la Vida y Sostenibilidad (APLV) fund in the Cauca Valley, Colombia.
3. The Problem

**Reliable access to clean fresh water is invaluable to sugar cane producers.** Dry seasons (June through July) caught the attention of sugar growers and mills, when base flow falls dramatically and increases risks for both human populations and sugar production. Also, increased sedimentation in the water supply – a result of land conversion as well as unsustainable grazing and agricultural practices – was an increasing concern to the water utilities and the sugar sector. Cutting-edge technologies promoted by CENICAÑA for water-saving irrigation are harder and more expensive to operate if water quality is deteriorated and sedimentation is increased.

The promotion of community organizations (river users' associations) has helped to support conservation activities that address these watershed stresses and water supply challenges in key watersheds of Cauca Valley from the early 1980's. Reforestation, restoration, protection of springs and environmental education were very common activities supported by the river users associations, and activities were usually implemented according to business opportunities without any scientific analysis. These decisions were typically guided by interest from landowners after socialization workshops, and funded by environmental authorities and the sugar sector. Science-based tools to increase impact and long term vision (in terms of quantifiable results that include robustness of activities to climate change) were still missing.

The APLV water fund aims to implement activities in the places where they are most likely to have an impact on sediment and baseflow and for the least cost. **Funds often want to use best available science and data to target their activities and obtain the highest return on investment; doing so requires detailed analyses of implementation scenarios to predict impacts on ecosystem services and to find the optimal portfolio of priority activities.** APLV wanted to develop a method for doing this kind of analysis that could be quickly replicated in the future. In addition, it was important that the prioritization take into account potential climate change in the area, as well as stakeholder preferences and local knowledge about what activities are feasible and where.

A project was initiated to improve the scientific basis for targeting activities within the water fund. Work started in 2010 by inviting water user association members living in the watersheds to identify potential work areas based on historical experience, preferences and knowledge of territory. **The stakeholder groups jointly agreed on the objective to “maintain consistent water flows necessary for drinking water, biodiversity and agriculture through a coordinated strategy.”** Past experience in the region has shown that activities to improve cattle ranching and small scale farming practices (such as protection, fencing, silvopastoral systems, forest enrichment and restoration) are feasible for landowners, given their likely opportunity costs. The outcome was a stakeholder’s map in which a set of these proposed activities was localized, including go and no-go zones (determined by security events). This information was digitized and used as the basis for the following analyses, to refine priority areas for the water fund to work.
4. Analyses & Methods

Over time, four sets of scenarios were developed:

1) Current climate conditions and land cover with multiple objectives: erosion control, enhanced baseflow, water yield and biodiversity
2) Current climate conditions and land cover with the single objective of erosion control
3) Portfolios using current land cover (same as #1), but targeted to future climate conditions and considering climate-induced changes in agricultural suitability
4) A “business as usual” scenario representing an ad-hoc investment strategy under current climate and land-use conditions

Scenarios 1 and 2 were compared to see how much different the recommendations and results would be if optimizing for a single service versus multiple services. Comparing Scenarios 1 and 3 showed how robust investments are to climate change. And Scenario 4 provided a way of quantifying how much of an improvement could be made by science-targeted investments versus an ad-hoc strategy of working with any willing landholder.

The creation of these scenarios was done using a complex, manual GIS process that later became the core of the Natural Capital Project’s RIOS toolset. Impacts of implementation on ecosystem services (what we call “return on investment”) were quantified using the Natural Capital Project’s InVEST models. An outline of the general process used for all scenarios (much of which also underlies RIOS) is provided here, both for selecting investment portfolios and quantifying return on investment from their implementation. Note that the original analysis was done on four watersheds, but we will focus on only one, Desbaratado, to illustrate the process that follows. We also look mainly at the top portion of the watershed (where most activities occur) so that detail may be seen more clearly.

4.1. Data

Spatial biophysical data used for all scenarios included current land use/land cover (LULC), topography (slope and other derivatives from a digital elevation model (DEM)), climate (precipitation and derived layers such as potential evapotranspiration (PET) and rainfall erosivity) and soil properties (soil depth, erodibility, and available water content). To delineate the area of interest, the geographical boundaries of each watershed and sub-watersheds within were defined based on the DEM. The InVEST Sediment and Water Yield models additionally require a table of biophysical coefficients that correspond to each land use type (such as root depth and USLE parameters), which were obtained through a literature search and by consulting hydrologists.

Additionally, the climate change scenarios used modeled precipitation data averaged across 19 General Circulation Models (GCMs) for the year 2050, with PET and rainfall erosivity derived from this averaged precipitation layer. Agricultural suitability was included in this scenario, where we took an average suitability score across 10 crops modeled spatially for future climate by the International Center for
Tropical Agriculture (CIAT). Biodiversity was taken into account through modeled species turnover for the timespan 2040-2069.

Stakeholders provided critical information by helping define which activities could be done and where (Figure 2). They drew on paper maps, indicating where activities should be done (for example, the headwaters of streams) or could not be done (for example, because of security concerns) and these paper maps were digitized.

**Figure 2.** Map of the Desbaratado watershed, on which stakeholders indicated where to do different restoration activities and where activities could not be done. Note that the watershed boundary shown here includes a portion to the east that is not included in our analyses.
TNC then provided a detailed accounting of the cost of each of these activities per hectare, taking into account labor, materials and transport over two years, the first year for establishment of the activity, and the second for maintenance. They also determined the overall budget that would be spent in each watershed.

4.2. Selecting investment portfolios

For each objective (watershed service) considered, we developed score maps that give the relative suitability of each parcel (in this case, a pixel in a GIS raster map) for different activities. To calculate scores, we defined a set of key biophysical factors that influence the effectiveness of watershed conservation activities in different places. For example, the factors for erosion control include: amount of erosion produced upslope of each parcel in the watershed; amount of sediment retention downslope of each parcel; potential for erosion on each parcel; potential for sediment retention on each parcel; rainfall erosivity; soil erodibility; soil depth; and riparian vegetation continuity. See the RIOS User Guide for more information on these objectives and factors.

In contrast, the biodiversity objective did not consider species diversity directly, as no relevant data were available. Instead, we combined factors that support higher levels of biodiversity - based largely on information in the land cover map - such as: amount of native vegetation in each sub-basin; patch size of native vegetation; and whether the native vegetation is inside or outside of currently protected areas.

Since each of these biophysical factors is expressed in different units (slope in %, soil depth in mm, for example), each factor was normalized so they could be combined into a single score map across the watershed. Each factor was also assigned a weight, indicating how important that factor is for influencing the objective, relative to the other factors. Score maps were created for each objective, combining the normalized factor values and weights as \(((\text{factor}_1 \times \text{weight}_1) + (\text{factor}_2 \times \text{weight}_2) + \ldots) / (\text{weight}_1 + \text{weight}_2 + \ldots)\). High values for these objective score maps indicate where it is the most effective to do either restoration or conservation activities in order to get the greatest improvement in the particular objective.

The next step was to prioritize where to do different activities across the watershed, based on how effective different activities are in achieving the desired land management change. The objective score maps (described above) were weighted by activity weights as \(((\text{objective}_1 \times \text{weight}_{o1}) + (\text{objective}_2 \times \text{weight}_{o2}) + \ldots) / (\text{weight}_{o1} + \text{weight}_{o2} + \ldots)\). Activity weights were selected based on expert opinion, and relate to the relative efficiency of a specific activity (e.g., reforestation or protection) for achieving a given objective. For example, the activity protection was given a higher weight than reforestation for erosion control, to reflect the fact that protecting existing páramo is more effective at reducing potential erosion than planting trees in degraded areas would be. High values for these activity score maps indicate where it is most important to do the particular activity, in order to get the greatest improvement across all objectives (Figure 3).
To reflect the stakeholders’ preferences for where activities could or could not be done, areas where each activity could not be done were removed from the map and areas where the activity was preferred had their score multiplied by 10, ensuring that they would be selected first.

To create the final activity portfolios, we used a geoprocessing script that selected the highest-scoring activity parcel (pixel), then the next-highest and so on, adding up the cost of doing the selected activity in each pixel, until the user-defined budget had been spent. Where several activities had the same score (could provide the same level of benefit), we assumed that the least-cost activity would be implemented. For this, we calculated cost-effectiveness by dividing the activity score by the cost of implementation, and the most cost-effective activity in that location was chosen for the portfolio. The result was a set of portfolio maps containing the recommended locations for doing each activity, based
on the stated objectives, preferences and budget. For Desbaratado, we developed portfolios reflecting five different levels of budget, from USD $387,875 to USD $775,750 (about COP $1.17 billion to COP $2.35 billion). Separate activity portfolios were generated for each scenario/watershed/budget level combination (see Figure 4 for one example).

![Diagram of selected activities](image)

**Figure 4.** An example of the multi-objective activity portfolio of USD $775,750 for the Desbaratado watershed (zoomed into the eastern part of the watershed), showing the best places to invest in activities to achieve all the fund’s objectives.

### 4.3. Quantifying return on investment

For quantifying and comparing the return on investment (ROI) that could result from implementing both targeted and ad hoc activity portfolios, we used two InVEST models: sediment retention and annual water yield. Primary inputs to these models include a land use/land cover (LULC) map, a corresponding table of biophysical coefficients for each land use type, climate, topography and soil data (see the InVEST User Guide for more information). First, each of these models was run using the current land
cover, without any water fund activities included, to establish the base level of sediment retention or water yield service.

For comparison, scenarios were created for each combination of scenario/watershed/budget, where the generated activity portfolio was combined with the current land use map to create a scenario LULC map as the input to InVEST, reflecting where new activities are being done in the context of the current landscape (Figure 5). New biophysical coefficients were also generated, corresponding to the new, transitioned land cover types (old LULC type->LULC type + activity.) For example, if an area that is ‘bare ground’ in the current LULC map is selected for reforestation, the biophysical coefficient of root depth will reflect this, and change from a very low value to the higher value representative of the root depth of the trees that would be planted there.

**Figure 5.** The selected activity portfolio map is added to the baseline land use/land cover map to create a portfolio LULC map. Both baseline and portfolio LULCs are used as inputs to InVEST for quantifying the difference in service between the baseline and a landscape where RIOS-recommended activities are implemented. Here, areas selected for the activity of Protection are protected, so retain their original LULC class.
Since one of the activities done in Cauca is ‘protection’, we wanted to value not only the change in service provided by the restoration activities (enrichment, fencing, reforestation and silvopasture), but also the marginal difference resulting from not allowing the protected areas (containing native vegetation) to degrade. So two sets of scenario maps were generated for each scenario/watershed/budget combination: one that only contained the restoration activities, where protected areas remained their original LULC class (called $\text{scenario}_{\text{protected}}$), and another that contained the restoration activities plus changed the protected areas into a ‘degraded’ LULC class (called $\text{scenario}_{\text{unprotected}}$). We assumed that if left unprotected, those protected areas would transition to pasture.

The sediment retention and water yield models were run on each of the resulting scenario maps, and the percent change in service from baseline was calculated as $(\text{scenario}_{\text{protected}} - \text{base}) + (\text{scenario}_{\text{protected}} - \text{scenario}_{\text{unprotected}}) = \text{total benefit}$. Within each scenario/watershed combination, the percent change was graphed against corresponding budget to see if there was some level of investment where benefits leveled off, indicating that no additional funds needed to be spent. Numerical and graphical comparisons were also made between the different scenario combinations described above: single-versus multi-objective, current versus future climate and business as usual versus targeted investments. The results are summarized below.

5. Results

The analysis described here produces several results that are relevant to APLV as it looks to target its activities in the most cost-effective and robust way. Activity portfolio maps (e.g., Figure 4) show the water fund where to invest to maximize improvement across the ecosystem services of interest, given a set of preferences, constraints and budgets. Activity score maps (e.g., Figure 3) give a more generalized view of higher- vs lower-priority areas for investment across the whole watershed, which can be used along with other criteria in the decision-making process. And return on investment (ROI) information can be used to choose between budget levels and/or scenarios and to study tradeoffs.

The scenarios analyzed for APLV allowed us to address these important questions:

- Comparison with baseline: How much could water fund interventions improve services over current conditions?
- Single- versus multi-objective targeting: How do outcomes change if you consider different objectives?
- Current climate versus climate change: How are portfolios different if you consider climate change? How does this impact ecosystem service outcomes both now and in the future?
- Targeted versus ad-hoc investment: What is the value of a scientific approach to targeting?

We will look at the ROI results for each of these scenario comparisons, and discuss the implications for water fund investments.
5.1. How much could water fund interventions improve services over current conditions?

Stakeholders are interested in optimizing investments across multiple ecosystem service objectives - erosion control, enhanced baseflow, water yield and biodiversity. We used InVEST to model the change in two services for which models were available - water yield and sediment retention. Ideally a fund would evaluate the change in all ecosystem services of interest using the best available quantitative models, however InVEST does not include a baseflow model and data were not available to run a habitat quality model for this area. We calculated the relative difference in service provision (the percentage change from baseline) between the current and portfolio scenarios at different budgets (Figure 6). This shows how much change can be attributed to implementation of the recommended water fund activities, and can assist in setting spending levels that will help to achieve quantitative targets. For example, in the Desbaratado watershed the improvement in services increases as budget increases, indicating that – at least up to the USD $775,750 budget – the fund is justified in spending the maximum amount of money possible.

![Desbaratado - Return on Investment](image)

**Figure 6.** Percentage change in water yield and sediment export for different budget levels, based on results from the InVEST models. These results include both the direct improvements from implementing activities and the avoided degradation from protecting native forest.

5.2. Single- versus multi-objective targeting
Since balancing across several services is likely to result in no individual objective being optimally improved, it is informative to understand the difference in service provision between this multi-objective targeting versus optimizing for a single objective. To test this in one watershed, a second set of portfolios was generated, with erosion control as the sole objective (Figure 5).

When sediment is the only objective considered, our prioritization method tends to bias protection of upland páramo instead of restoration and silvopastoral activities throughout the watershed. This effect can be seen clearly in Figure 5. Because the activities fencing and protection are much cheaper than the other activities considered, this means that activities are implemented over much more of the landscape in the single-objective than in the multi-objective scenario.

These portfolios were also run through the InVEST Sediment model and the results compared to the multi-objective scenario. At lower budgets, the portfolios targeted at sediment retention perform better in terms of controlling sediment export in the river: a reduction of 23.76% in sediment export at USD $387,875 compared with only 22.29% reduction with multi-objective targeting. However as the budget increases, the multi-objective portfolios actually performed better in terms of decreasing sediment export: a reduction of 38.27% at USD $775,750 for the multi-objective portfolio compared to a reduction of only 34.36% for the single objective scenario.

These results are driven by differences in the way that the single- and multi-objective portfolios select priority areas and the way that the InVEST sediment model estimates changes in erosion and transport. The single objective portfolios – which focus entirely on sediment retention – are biased towards protection of upland páramo, especially at higher budgets. The prioritization algorithm assumes that the high slopes and water yield in that area would result in a high risk of sediment erosion if those lands were degraded to pasture. The multi-objective scenario, however, directs more activities to riparian corridors throughout the watershed, because our method assumes higher importance of these areas for regulating baseflow. The assumptions and data that were used to drive the InVEST sediment model, on the other hand, result in the areas closest to the streams (e.g., riparian corridors) being most effective in trapping sediment erosion, and pasture in the upland páramo does not have a large negative impact on erosion (based on the parameter inputs used in this analysis). In reality, upland páramo is critically important for regulating baseflow in Andean systems, which reveals a limitation in the modeling approach used here. Future work is needed to improve the data on sediment erosion and retention that goes into InVEST and RIOS, in order to reconcile the conflicting assumptions between the two modeling approaches.

The priorities for APLV are both dry season base flow and sediment retention. Therefore the fund was most interested in portfolios that balance both of these goals. This analysis shows that there can be a significant improvement in sediment retention even with a balanced portfolio, along with modest improvements in annual water yield (Figure 6).
Figure 7. Comparison of selected activity portfolios in the Desbaratado watershed. The left portfolio is for the multi-objective scenario, USD $775,750 budget. The right portfolio is for the same budget, with the single objective of erosion control. Many activity locations are similar between the two scenarios, but changes in Fencing are particularly clear in the erosion-only scenario, moving to the top of the watershed where the slopes are much steeper and more prone to erosion.

5.3. Current climate versus climate change

Water funds are often planning to make watershed investments over a long period of time. Taking climate change into account from the onset can help make those investments more robust and applicable into the future. For example, changes in rain patterns may lead to a change in where crops are grown. This will affect where nutrient and sediment loads are increased, leading to a change in the best places to invest in improved agricultural practices or riparian buffers.

CIAT has done future climate modeling for the Cauca Valley, providing projected precipitation maps as well as maps of agricultural suitability change and species turnover. Using these data as inputs, the InVEST models predict a 13.0% increase in sediment export and a 4.7% decrease in water yield under projected future climate conditions.

The future climate precipitation maps were used both in the portfolio selection stage, influencing where activities would be done, as well as in the return on investment modeling, as InVEST model inputs. Agricultural suitability was added as an objective in the portfolio selection for future climate, assuming that places with a high change in suitability are places where agriculture is likely to expand, and maintaining investments there will be more difficult. Species turnover was added as another factor in

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the biodiversity objective, such that activities would not be chosen in areas with high turnover, so that these places would retain their species richness into the future.

**Figure 8.** Comparison of selected activity portfolios in the Desbaratado watershed. The left portfolio is for the USD $775,750 budget, multi-objective scenario. The right portfolio is for the same budget, climate change scenario. Note how some activities have moved higher in the watershed, driven by changes in precipitation patterns and related changes in where it is suitable to grow major crops.

We used the InVEST models to compare the performance of the multi-objective activity portfolios (targeted to current climate) and those targeted to climate change conditions. The change in sediment and water yield for all the scenarios is calculated in reference to the baseline (current land use and climate). The results show that there are potential trade-offs to consider when selecting robust investments for future conditions. Because the climate change portfolios assume that maintaining investments will be more difficult in places with increasing agricultural suitability, many of the investments have been relocated to the upper portions of the watershed. Currently, the upper watershed is páramo and shrubland, but in the future, agriculture is likely to displace these as it moves upslope. Our scenarios were limited in that they only considered future climate projections, not future land use/land cover changes. Therefore we only evaluated the impact of changing climate drivers and not the impact of changes in where agriculture will actually be done. If future land cover maps were available, the change in service provision would likely be different, since the activities would be located more closely to future agricultural areas, and therefore have more impact. The climate change portfolios are therefore less effective at retaining sediment than the current climate portfolios. However the climate change portfolios show a greater positive effect on water yield than the current climate portfolios, due to increased protection of the highland páramo (Figure 9).
Figure 9. InVEST model results for current climate and climate change-targeted portfolios. Blue bars are the multi-objective portfolios targeted to current climate conditions, and gold bars are the portfolios targeted to climate change. Solid bars show portfolio performance under current conditions, while dotted bars show performance under future climate conditions. The change in sediment and water yield for all the scenarios is calculated in reference to the baseline (current land use and climate). The change in sediment and water yield under future conditions where budget = 0 shows the impact of climate change alone.

Note that these results show only the expected change in sediment and water yield, not the other services considered in portfolio design. We would expect the climate change portfolios to perform better at maintaining species richness, since change in habitat suitability was used in the prioritization.
Although the current climate portfolios appear to perform better in some ways, the suitability and longevity of the portfolio may not be as robust as for the climate change portfolios. This analysis reveals that some trade-offs can exist between considering only current conditions in portfolio design versus ensuring long-term robustness.

5.4. Compare to ad-hoc investment

Water funds’ restoration and conservation work is often sited primarily based on whichever landowners are willing to participate, leading to a fairly random distribution of activities across the watershed. The goal of incorporating a science-based approach to site selection is to improve outcomes over such an ad-hoc investment strategy (i.e., enrolling any willing landowner regardless of location). To show how much may be gained by biophysical targeting, we quantified the difference between service provision under an ad-hoc method of activity site selection and the modeled activity portfolios.

To simulate ad-hoc investments, we generated activity score maps which were analogous to those used for the budget scenarios described above. In this case, we create 10 score maps for each budget level in which the individual pixel scores were assigned random numbers, not based on any biophysical information. Stakeholder information on where activities could or could not be done was still used, assuming that these preferences and restrictions would be taken into consideration even if the fund used an ad hoc strategy. Activity portfolios were generated based on the random score maps, meaning that activities were assigned to pixels regardless of their potential biophysical benefit, just as if the fund allowed ad hoc enrollment. The InVEST Sediment model was run on each of those portfolios, and averaged over the 10 runs for each budget level. These averaged model results were compared with the multi-objective scenario (Figure 10).

The results show that targeting investments using our scoring approach significantly improves the potential for ecosystem services improvement. For sediment, the relative improvement over ad hoc investment \( \text{total}_\text{benefit}_{\text{targeted}} / \text{total}_\text{benefit}_{\text{ad-hoc}} \) ranged from 482% at the USD $775,750 budget to 677% at the USD $387,875 budget. The gains from targeting investments are seen most strongly at lower budget levels. When budgets are limited, the area that APLV can implement activities on is much less, so targeting key areas for ecosystem service provision is the most critical.
Figure 10. Return on investment from targeted portfolios (hollow diamonds) compared to untargeted portfolios (solid circles), in terms of the percent change in sediment export, for the Desbaratado watershed.

6. Conclusions and Next Steps

The approach demonstrated here in APLV is useful to bring a landscape-level ecosystem services approach to the process of choosing implementation sites, potentially reducing the amount of time spent up-front in costly field assessments and modeling by narrowing to a portfolio of potential sites with the greatest impact. At all stages in the analysis, we incorporated feedback and local knowledge from river association leaders, local community leaders and landowners, ensuring that the results would be feasible for the fund to implement.

In addition to using activity portfolios (e.g., Figures 4, 7, and 8) to direct water fund activities, activity score maps may also be useful to identify “hotspots,” or general areas where particular activities would be effective and where additional analyses may be cost-effective (Figure 3). Activity portfolios for different budget levels can help the fund to decide on a reasonable target budget and the sequencing of activities as more and more money becomes available through time.

By looking at how optimal activity portfolios might change under future climate conditions, the fund can look for the best places to invest where activities will continue to have benefits far into the future. The portfolios shown here – ones that take into account changing climate as well as changing agricultural and habitat suitability – will help APLV to make investment decisions that are more likely to be robust in the future. We were not able to do a full analysis of future benefits under climate change conditions in
this analysis, but the results shown here did indicate that there are potential trade-offs between short- and long-term benefits of the fund’s investments. Having modeling results that make these trade-offs clear to fund investors and board members helps the fund to better understand their options and to make transparent decisions that balance current and future needs.

Comparing the outcomes from targeted portfolios with business as usual (ad hoc investment) shows the added benefit that the fund can get from applying a science-based approach. This helps to justify the allocation of private and public funds to analyses like those presented in this document. Although science-based targeting can take time, our analysis shows that — for sediment, at least — activities may be from 4 to 7 times better at reducing sediment in streams. This can result in significant benefit to the fund’s contributors. New tools like RIOS also mean that these analyses are now faster to implement.

Modeling expected activity impacts with InVEST can also be useful in designing impact monitoring, by identifying places where impacts are likely to be greatest at the site, micro-watershed, and larger scales, and setting targets against which monitoring data may be compared. APLV has recently implemented a multi-scale monitoring program to track how the watersheds are responding to water fund activities and other land management changes, as well as socio-economic impacts to small landholders. These monitoring data can also be useful for validating and improving watershed models, to make further analyses like this one more accurate.

Targeted portfolios are still being used in APLV decision making. Priority sites identified through this science-based process are the first option when the water fund selects projects to be funded. The selection process is then completed with field visits, validation of the current situation of the properties, and the willingness of landholders to participate.

Also, APLV is working in new watersheds as requested from new water fund supporters. The approach is clearly accepted by APLV staff and is beginning to be included as part of the normal process for selecting sites and working with local partners going forward. APLV’s board members and technical secretary are now aware of the importance of science in decision making, as compared with the ad hoc investment approach common over the last 20 years.

Finally, research and academic institutions such as Centro de Investigación para la Caña de Azucar (Research Center for Sugar Cane; CENICAÑA) and Corporación Autónoma Regional del Valle del Cauca (Regional Autonomous Corporation of the Cauca Valley; CVC) have asked APLV to share this invaluable information as they begin similar analyses in different areas in which they work.

It is important to remember that the ability of water funds to do watershed conservation will always depend on building and maintaining relationships with stakeholders in the area. These relationships will continue to be very important for determining ultimately where a water fund can, and cannot, do activities. For this reason, the modeling approach we present here is meant to augment how the water fund allocates their resources, not replace it. As seen in the Cauca Valley, these kinds of analyses can help to bring together diverse actors who have similar goals, to better link their efforts in a coordinated manner that benefits everyone.