Evaluating Green Infrastructure for Public and Private Investment: 
*Lessons from Lima, Peru*

Mark S. Kieser  
Senior Scientist  
Kieser & Associates, LLC

Special thanks to:  
Gena Gammie  
Program Manager, Water Initiative  
Forest Trends  
And  
Bert Debievre  
Condesan
Lima, the second-largest desert city in the world, experiences a dry season deficit of over 40 million m$^3$ of water each year.

**Average Water Supply and Demand, Rimac River Basin.**
Source: Peru Ministry of Agriculture (2010)
30-second Watershed Tour
Green infrastructure...the sponge to turn excess water in the wet season into crucial dry season flows.
Estimating benefits of “Green” Infrastructure/Practices in Upper Watershed Areas

• Livestock management interventions
• Restoration of wetland hydrology
• “Amuna” restoration
Innovation: assessment amidst uncertainty

**GOAL**
Order-of-magnitude estimates of cost-effectiveness and potential benefits

**CHALLENGE**
Significant data gaps; limited flow monitoring

**Need**
Effective Water Fund (Aquafondo) investments
Analysis relies on estimates of hydrological benefit of a typical project.

• Estimating cost-effectiveness
  Cost of average project/baseflow benefit of average project

• Estimating potential impact
  Baseflow benefit of average project * potential number of projects
Estimating benefits: livestock management interventions

Mass budget Equation

A water and soil water mass budget is represented by the following equation:  

\[ P - ET - c^*\Delta S - \Delta G - \Delta L \]  

(1)

Where:

- \( P \) = precipitation
- \( S \) = soil moisture
- \( Q \) = streamflow
- \( G \) = groundwater
- \( ET \) = evapotranspiration
- \( L \) = leakage

Assumptions:

1. \( ET \) remains the same before and after intervention.
2. Change in groundwater is nominal before and after intervention.
3. Leakage remains the same before and after intervention.
4. All infiltration initially counted as soil moisture.
5. The soil moisture coefficient, \( c \), can be used to adjust for assumptions 1-4.

The equation simplifies to:

\[ Q = P - c^*\Delta S \]  

(5)
Estimating benefits:
livestock management interventions

- Calculate Runoff Reduction
- Calculate Soil Moisture Increase
- Calculate Increase in Baseflow Volume (m$^3$)
- Calculate Increase in Baseflow (m$^3$/s)
Estimating benefits: hydrological restoration of wetlands

Figure 1a. Conceptual cross-sectional diagram illustrating a drained wetland via a constructed ditch which eliminates surface storage (that would otherwise be contributing to groundwater recharge), and a dewatering (lowering) of the local groundwater table. (P = precipitation)

Figure 2b. Conceptual cross-sectional diagram of a wetland restored by removing the drainage ditch. This allows for surface storage, groundwater recharge and restored local groundwater levels. (P = precipitation; ET = evapotranspiration; Q = stream baseflow)
Estimating benefits: hydrological restoration of wetlands

- Estimate amount of wet season precipitation that will be stored in restored wetland
- Calculate baseflow volume (m$^3$)
- Calculate increase in baseflow (m$^3$/s)
Estimating benefits:

Restoration of Amunas (ancient diversion channels)

Figure 3. Conceptual schematic (plan view) of a diversion channel directing flow to an infiltration ditch increasing groundwater recharge and eventually, stream baseflow of the original stream during dry periods. (Transport pathways are italicized. Arrows indicate flow path; red infers a loss from baseflow contributions.)
Estimating benefits: Amuna restoration

1. Measure discharge from diversion channel
2. Subtract out flow ‘lost’ to Ag use, ET, etc.
3. Calculate volume of infiltrated water (m$^3$)
4. Calculate Increase in Baseflow (m$^3$/s)
This ‘sponge effect’ can substantially decrease water stress...

135% potential reduction of dry season deficit

Source: Forest Trends analysis
Competitive with gray infrastructure

Sources: Forest Trends analysis
Approach can be credibly applied for a variety of purposes, advancing green investments while monitoring to improve estimates ‘catches up.’

- Justifying public investments by quantifying hydrological benefit for cost-benefit analyses
- Estimating impact of private sector voluntary compensation
- Prioritizing investments and estimating impacts of a water fund (in Lima, and in other cities)