**Five sentence blurb**

I worked on a method that would let us estimate the irrigation going on in a basin by looking at streamflow. The premise of my work is that there should be a way to estimate the kinds of water supply and management practices that’s happening in a catchment by looking at streamflow and some remotely sensed data. Specifically, I’ve decided to focus on developing a method for estimating irrigation practices happening in a catchment based on how it changes natural streamflow. Our question was to differentiate among four different irrigation sources, importing from outside the catchment, pumping from a river, pumping from a shallow aquifer that’s connected to the stream, and pumping from a deep aquifer that’s not connected to the stream. I’m looking for fingerprints these irrigation sources leave on natural streamflow. I found that there are three streamflow metrics describing changes from natural streamflow that we can combine into a fingerprint that can help us differentiate among four irrigation sources. We also found that our model can predict water crisis syndrome that might result from each irrigation source.

**Introduction**

The premise of my work is that there should be a way to estimate the kinds of water supply and management practices that’s happening in a catchment by looking at streamflow and some remotely sensed data. We want to be able to apply these kinds of method to PUB efforts.

Existing PUB efforts usually focus on predicting streamflow in undisturbed natural basins. It’s based on the assumption that basins with similar natural characteristics will have similar streamflow patterns. But, given the high level of disruption of many basins from natural conditions, we think that incorporation of human activity prediction in PUB is an important next step in the field.

**Expand PUB methods to irrigation basins**

Specifically, I’ve decided to focus on developing a method for estimating irrigation practices based on streamflow. Irrigation is one of the most common human disruptions in basins around the world, and is a great place to start developing a method.

My first step is to look at how streamflow changes with a variety of irrigation sources in a given catchment. Then, I’ll come up with a “fingerprinting” method that relates streamflow back to the irrigation happening. This type of fingerprinting will help us make predictions on irrigation based on streamflow data.

We looked at four sources of irrigation: import from outside, withdrawal from a river, pumping from a shallow aquifer that’s connected to the river, and pumping from a deep aquifer that’s unconnected to the river. Our question is can we differentiate among these sources based on streamflow fingerprints?

If you look at this graph, you’ll see streamflow timeseries of catchment that requires irrigation. Here we’ve assumed that 10% of the area is irrigated and that people irrigate based on soil moisture. Irrigation is perfectly synchronized to the need, and if the source can’t provide enough water, then no irrigation happens. So the volume provided in irrigation differs for each source. The black line is the natural, non-irrigated condition. The colored lines each represent irrigation using a particular source. Blue is import from outside the basin; red is direct channel withdrawal, and purple and green are shallow and deep aquifer pumping.

There are a few things to note here. You can see that importing water increases streamflow, and the other sources decrease streamflow. There is also saw tooth pattern in some of these lines, particularly the import and deep aquifer sources, which arises from periodic irrigation.

The change in streamflow magnitude and these sawtooth patterns can be summed up in three streamflow parameters: Qbar (average streamflow magnitude), alpha (average peak height), and lambda (average peak frequency). We use percent changes in these metrics to develop a fingerprint.

**Irrigation can be tracked in streamflow fingerprints**

We used percent change in each of these three metrics from natural conditions to come up with a fingerprint of irrigation. The contour plots show percent change in alpha for four sources and 400 catchments. The change in the value of each metric depends on the catchment type. The vertical axis represents timescales of refilling versus depletion; and the horizontal scale is volume to be filled versus volume to be provided by rain. The horizontal axis is the ratio between the soil storage capacity and the mean rainfall input per event, and the vertical axis is the ratio between the rate of occurrence of rainfall events and the maximum evapotranspiration rate. These two dimensionless groups define the interaction of the most important climate, soil, and vegetation parameters in soil moisture dynamics.

We can look three catchments in particular. It’s clear that it’s possible to differentiate among the sources for each catchment using this fingerprint, but it’s also clear that the fingerprint of irrigation may change slightly for each catchment.

If we know the climate and soil characteristics of an irrigated catchment, we can locate that catchment in these plots. If we can then model a “natural streamflow” for the catchment, we can compare that to actual streamflow data calculate percent changes in each of the three parameters, and create a fingerprint for that catchment. Then, we can go back to these contour plots and locate our catchment within plots for each source type, and construct what the fingerprint would look like for each source, and estimate, by comparing the actual fingerprint to the four hypothetical fingerprints, where the irrigation water is coming from.

We might also be able to eliminate some irrigation sources in certain cases. First, if the catchment falls in the bottom right, hashed region, the given source can provide less than 50% of required irrigation. This is an unrealistic irrigation scenario, and we can eliminate the corresponding source as a possibility. Second, in humid catchments, irrigation wasn’t needed, so we can conclude that no irrigation is being done.

**Environmental Implications**

We can also go a step further and predict water crisis syndromes like unsustainability (in depletion of groundwater or shallow aquifer), ecological destruction (in large perturbation of streamflow volume) and social impact (the ability or inability of the given irrigation source to provide a basin’s irrigation needs).

These contour plots have the same layout as the previous set – catchment characteristics are collapsed into two dimensionless numbers, and they show environmental impact of each of the four irrigation sources.

A rating of bright green, indicates that irrigation is provided without negative impact on sustainability or ecology. This happens for all catchment types if irrigation is imported, some catchments for deep aquifers, and a very small fraction of catchments for shallow aquifer pumping.

**Future Work**

In sum, we looked at how irrigation affects different streamflow metrics and predicted how each irrigation strategy would impact water crisis syndromes. This work was the first step towards expanding PUB efforts to make predictions about irrigation in heavily managed basins. We’ll expand our models of irrigation by modeling other realistic irrigation strategies, such as fixed schedules and the crop coefficient method.