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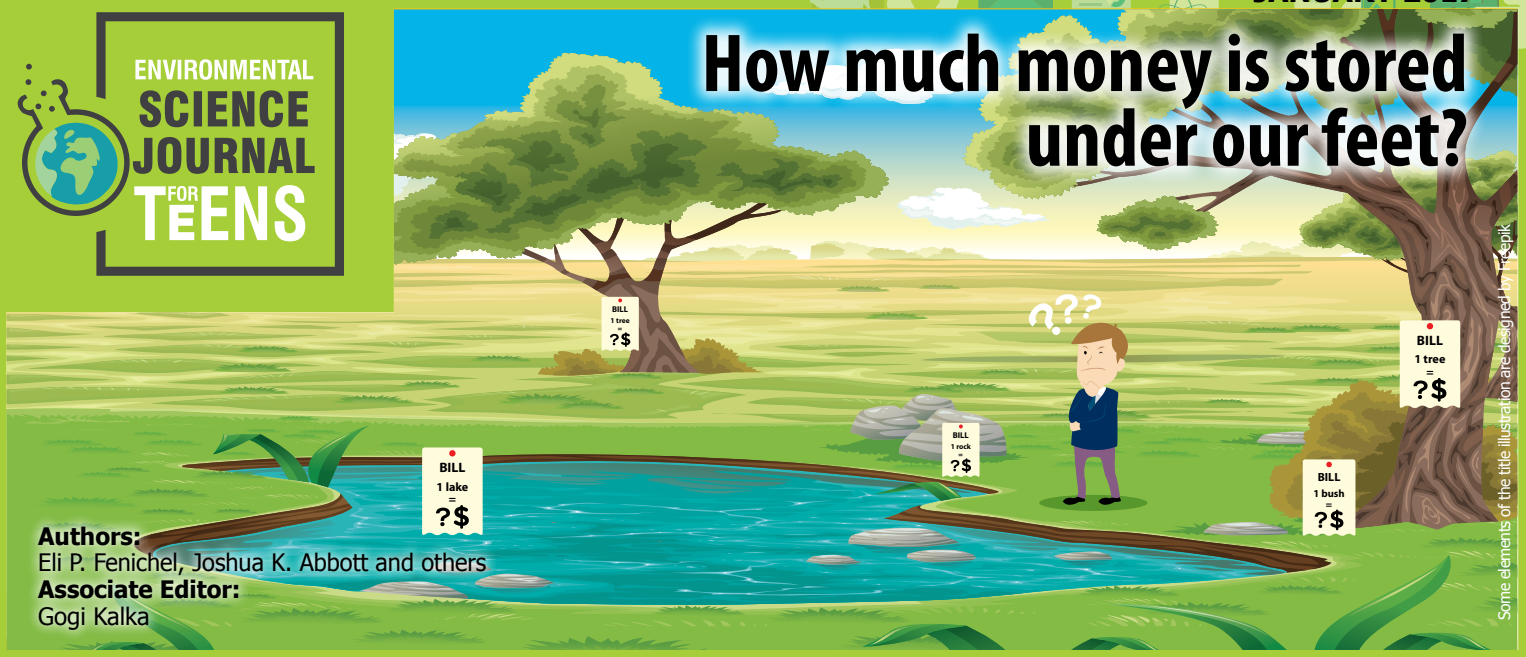
How much money is stored under our feet?



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Abstract

For over 100 years, scientists and economists have struggled to figure out how much money our *natural resources* are worth when left untapped in Nature. We addressed this problem by creating a new formula to measure the value, in money terms, of leaving natural resources in place. We then picked a case study (a real life example) to illustrate our formulas: we investigated an agricultural area in western Kansas that grows crops using groundwater. These underground water resources are stored in the High Plains Aquifer. We thought of the *aquifer* like a bank account and asked how much money Kansas pulled out of its groundwater "bank account" over a period of 10 years.

The number turned out to be large: $110 million per year, which is more than twice the amount Kansas spent on schools in that time! Our study shows that we have to take the value of Nature into account when planning how to use its resources in order to make wise and *sustainable investments* for our future.

Introduction

Natural resources provide valuable *services* to people like clean air, food, and shelter. Consider water: it's essential for survival. Yet only 1% of all water you can see from outer space is freshwater and easily available to people. Water is *scarce*, which means there is less of it than people would like.

So how much is water worth? Is it the amount you pay in the supermarket for a bottle of water? Or is the story more complicated? It *is* much more complicated. To understand this, you must first understand a *price*. Prices measure *scarcity.* You know this first-hand as consumers. For example, when the supply of milk falls, the price we pay at the supermarket tends to rise to reflect this scarcity.

However, there are no market prices for many natural resources. In the case of irrigation water, for example, there is no store where we can check the current price. Even if farmers are charged for the water they use, this price doesn't reflect its value in the ground to future farmers. So to assess its price, we need to understand how much is available, how much people want it, what uses they have for it, and how much they save for later. Then we can measure changes in value even if we cannot measure the total value. This is important in the case of water, because the last drop is likely priceless. However, the first few liters might be easily traded away for something else that we like.

In the past, when economists wanted to calculate how much a resource was worth, they often assessed the *costs* of preserving it (like stopping a forest from deforestation) but ignored how much financial benefit it provides. We wanted to change that.

Methods

We developed a new formula that puts a specific dollar amount on the benefit society gains from saving a natural resource like water so we have the opportunity to use it in the future. This is different than the value we might get from using it today. This allows us to compare water's value with other *capital assets* (things that can be used now or in the future) like houses or machinery that are relatively easy to value in dollars.

We took previous calculations used in *economics*, adapted them, and combined them with computer models of how Nature and human behavior change over time – much like building a video game of water use. That allowed us to come up with a novel (new) formula that makes it possible to measure the changes in wealth, in dollars, stored in a natural resource for future use in a certain area.

To illustrate our model, we investigated water stored in an underground *aquifer* (an underground water supply) in Western Kansas (Fig. 1). We studied the planting decisions farmers made between 1996 and 2005 and how much groundwater farmers used to irrigate those crops. We then used our new formula to calculate how much value famers pulled out of the groundwater bank account for this area in Kansas by using that groundwater.

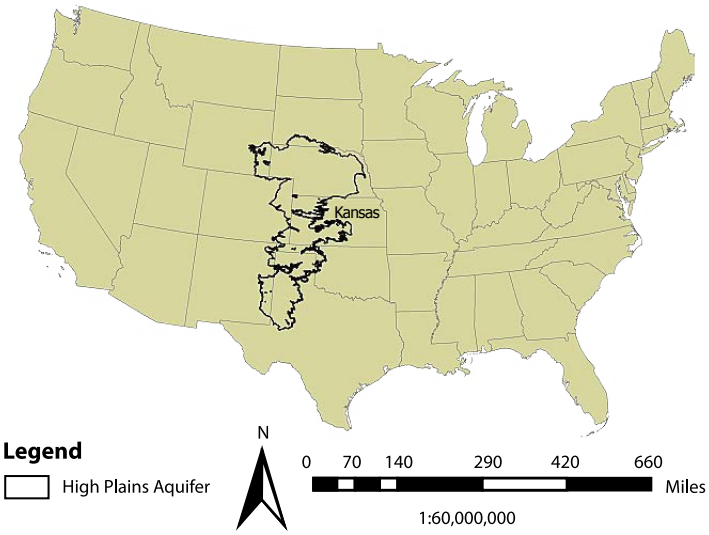


Figure 1:
The High Plains aquifer. (Credit: Kansas Geological Survey)
https://goo.gl/maps/WUd9zfE1fmJ2

Results

In the 10-year period we studied, farmers in Kansas used up so much of the groundwater in the High Plains Aquifer that its level sank on average by roughly one foot.

Interestingly, we also saw that more and more farmers started to use water-efficient (water-saving) drop nozzles for irrigating their field (Fig. 2), but the groundwater levels in the aquifer still declined (Fig. 3). The new technology saved so much water that farmers were driven to grow more water-hungry crops and even farm on lower quality land. This made the stored water less valuable. This motivated the farmers to use more water than they would have without the water-saving device, which makes the stored water more valuable. Our formula accounts for both forces.

We plugged these numbers into our formula to calculate how much money all this lost groundwater might be worth and showed that the amount was huge: about $110 million US dollars per year. That is more than twice the money Kansas spent on schools in 2005!s

Figure 2:
Drop nozzle irrigation technology in action. (Credit: Kansas Water Office)

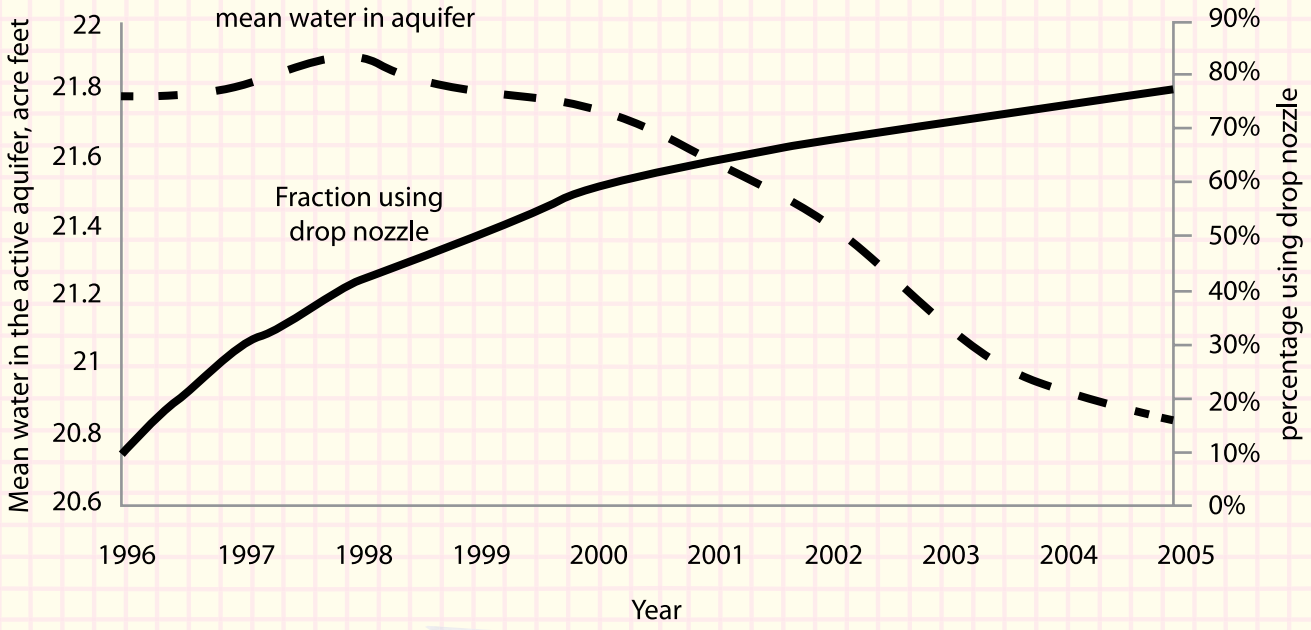
Please see page 3, Figure 3

Figure 3:
The average amount of water left in the aquifer and the percentage of farmers using drop nozzle irrigation devices for the same period of time.

What kind of correlation can you see?

Correlation = a relationship between two trends in the data in which one increases as the other increases (if it's directly correlated) or the one decreases as the other increases (if it's inversely correlated). For example, the more farmers used drop nozzle irrigation devices, the lower the aquifer level fell (See Fig. 3). Correlations are easy to demonstrate - you just need to plot the data. They do not, by themselves, prove a causation.

Causation = a relationship between two sets of data in which the trend in one of the sets causes the change in the other. For example, as the temperature in a heating pot of water rises, the amount of water in the pot decreases (as it evaporates). Now look at Fig. 3 again: the correlation observed there doesn't automatically mean that the farmers' switch in irrigation technology caused the aquifer level to drop. There could be other factors at play.



Discussion

Groundwater is important to people, butthis wealth can easily be lost as the resource is depleted. Economic theory predicts that when things are desired but limited, they increase in value. So the value of the groundwater went up the more it was used, but changing technology (drop nozzles) also lowered the need for water, which also made saving water less valuable. This means that while the water level dropped by about 0.4% per year, the dollar value of the lost water fell at a much higher rate of 6.5% per year. Over the 10-year period Kansas took $1.2 billion out of its water "account." People who think about *sustainability* would say that at the very least that means Kansas should have spent at least $1.2 billion on other capital assets in order to provide future generations with as many possibilities as the people of Kansas had during the 10-year period studied. We don't know if this happened, but hope it did. If it did not, then it would be hard to argue that Kansas was being managed sustainably.

Measuring the value of stored natural resources will help us compare the cost and benefits of using resources to other investment options. Sometimes it makes sense to convert natural capital into other forms of capital, such as knowledge (through funding education or research) or infrastructure (like roads); other times it makes more sense to leave the resource as is.

Conclusion

Natural resources are like a great gift of money. You have options what to do with it:

- spend it right away (i.e. use it up),
- save it to use it in the future, or
- use some to convert it into other ways of generating wealth.

You can help conserve our water resources by being careful with your own water use:

- Take shorter showers
- Turn off the tap while brushing your teeth
- Only water your lawn in the early morning or late evening, when evaporation will be limited

Encourage your parents to buy energy-efficient appliances.

Glossary of Key Terms

Aquifer – an underground layer of water-holding rock, gravel, or sand, from which groundwater can be extracted using a water well.

Natural resource – anything that people can use that comes from Nature and can persist over time. Natural resources require biological or geological processes to be produced and cannot be produced solely through technology. Examples include air, water, forests, soils, fish, oil, iron ore, and coal.

Ecosystem service – benefits that people get from Nature. Examples include a drink of clean water, food for a meal (from plants and animals), the experience of hiking or other outdoor recreation, and much more.

Capital asset – Something durable that stores wealth and passes it to the future or is used to generate wealth by providing services. Examples include a brick of gold, a house, or a piece of machinery in a factory.

Economics – A social science that focuses on understanding trade-offs in human decision making, often focusing on the factors that determine the production, distribution, and consumption of goods and services.

Price – the ratio of exchange between two goods or services. For example:

- If a hamburger costs $8, then the ratio is 8 dollars to 1 hamburger or $8/hamburger.
- You might be willing to trade 1 hour of time lawn-mowing (a service) for $12. The dollar price in this case is $12/hr.
- Notice that by dividing these ratios we change the units of the price to hr/hamburger (exactly 0.75hr/hamburger). This is also a price, but it is now in the units of hours.

Scarcity – The availability of something compared to how much people want it. Being rare does not make something scarce. For example, Ebola is rare in the world, but it is hardly scarce – there is still much more of it than society would like. Water, while plentiful globally, is scarce in many places, because most of the time we would always like a little bit more for some valued use.

Sustainability – Managing resources to meet the needs of the present without compromising the ability of future generations to meet their own needs.

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Check your understanding

1. Adam Smith, a famous economist in the 1700s, noticed that water is much more important for life than diamonds are, but that diamonds fetched a much greater price. He called this the water and diamonds paradox. Can you explain it?

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2. This paper focuses on water as an important natural resources for humans. Can you think of three others natural resources that are important to us, and why?

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3. What other services do ecosystems provide for us humans? Name at least four.

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4. What factors could contribute to the difference in price and/or value of water? Think of the water bottle in a supermarket.

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5. The center pivot nozzle was designed to make watering crops more efficient. However, there is evidence that it actually increased farmers' water use overall. Can you think of other possible examples where technologies designed to conserve resources like electricity or gasoline might actually encourage people to consume more?

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6. Can you think of some ways to save water in our daily lives?