The intrinsic value of water: a proposal

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Abstract

This paper returns to the controversy about the Intrinsic Value of Water (IVW) which should be included in the price paid by the consumer. The IVW is calculated based on the solar energy involved in the water cycle, which annually generates a considerable volume of water of the highest quality without human intervention. In 2014, Mexico invested a budget of 3,700 million USD in water management. This came mainly from government subsidies, with a quarter coming from water rates. The volume of water available is 459 km^3, approximately 16.5% of which comes under the field of federal administration, including the volume of dams and the concession of rivers and groundwater. The federal budget divided by the volume of managed water is the water cost (0.043 USD m^{-3}). The federal agency delivers the water in bulk to the states and the municipalities through the Watershed Councils, who determine the price of water to users based on their availability nationwide. The energy required to evaporate the water of the annual precipitation in Mexico is 1.01×10^{12} kW h $year^{-1}$. This energy is divided by the precipitate volume and then multiplied by the lower price of kW h to calculate the intrinsic value of water: 0.036 to 0.13 USD m^{-3}. The federal, municipal and intrinsic costs are added to calculate the final value. The IVW is a kind of natural goodwill that each country should pay according to their hydrological balance.
Keywords: hydrological balance, water and electricity cost, added value.

1 Introduction

Water is an essential substance for sustaining life on the planet in all its forms and at all levels. From bacteria to blue whales, water is needed as a matrix for biochemical reactions, as a reagent or as a structural unit at the cellular level, organ

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or system; to transport metabolites to and from the cell; for moving people or goods, and eliminate waste for sanitation [1].

Does water have a price? The answer to this question is definitely no. Despite this overwhelming response, the question is relevant in Latin America, where the weather hinders access to water, in Mexico and other meridional countries, contrary to what happens in the temperate countries of the Earth. The amount of water is limited in the tropics due to aridity and its heterogeneous distribution. With the growing human population and its productive activities, water increasingly becomes a critical resource, because of its limited capability to meet the rise in demand and its progressively intensive use (Anton [2]).

Over time, the combination of these three factors intensifies the competition between individuals, communities and states, all of whom are struggling with different physical, political or commercial ways to secure access to this vital fluid without interference from potential competitors (Wetzel [3]).

However, among informed people, such as among the civilized nations, agreements are generated to ensure equitable distribution, to mutually determine the volume and the use to which it will be put, and to penalize those who abuse or do not respect the conditions set up by mutual agreement. Sanctions can be administrative, seeking justice through redistribution of volume, and economic, which consist of monetary fines for violators.

The problem with transactions and economic sanctions lies in assigning a price for water. The same problem arises when attempting to charge the population for the distribution service . When attempts are made to determine the price, it is found to be subjective and dependent on the use (Solís [4]).

What does it cost nature to produce a liter of water? How much does a liter of wasted water cost? How much does it cost for a rainy area and an arid area? Is it a truism to state that, regarding the latter, the price depends on the law of supply and demand? Which is cheaper, seawater or spring water? Groundwater or surface water? For irrigation or for drinking? An example of proposals to fix the price of water in the USA is developed in Raucher [5].

In thinking minds there is no answer to the intrinsic value of water. Some propose that its value is the cost of chemical synthesis in a laboratory from two moles of hydrogen and one mole of oxygen of which it is constituted, but usually it is given a price equal to the cost of collection, treatment and distribution in terms of equipment, material and manpower plus an aggregate result of demand and surplus, which gives the consumer price. However, it is not easy when people abuse facilities and waste water.

2 Objective

This paper develops a proposal for determining the intrinsic value of water from the Earth's water cycle, which makes it available for the multiple uses that man puts it to and for nature conservation. Water management in Mexico will be used to illustrate the theme.

3 Background

3.1 The hydrologic cycle

The sun is constantly disintegrating. Its huge mass generates a gravitational force so great that the resulting pressure in the core increases several orders of magnitude compared to its temperature surface. Convection mobilizes masses of solar material that emerges violently as massive explosions that throw matter and energy permanently into space. The matter is mainly gas, while the energy covers a wide range from cosmic rays to radio waves (Gates [6], Ghosh and Prelas [7]).

The energies corresponding to solar ultraviolet radiation, visible light and infrared are relevant for the purposes of this paper. These energies, impinging on the upper surface of the atmosphere, are in part reflected back into space and partly transmitted to the surface of the Earth. This last part warms the air, soil and water by the phenomena of scattering and absorption of radiation, generating on the planet an average temperature of 15°C (mean value between the maximum and minimum recorded levels). If not, the Earth would be a large indoor ice ball wandering inert in its orbit (Gates [6], Nobel [8]).

Heated material converts radiant energy into heat (Q), and the heated water evaporates in gaseous form to the air. Vapor rises into the sky and becomes clouds that are then transported by air currents in all directions. When they reach the continents, clouds rise as they hit the mountains and cool without losing heat (adiabatically), then re-condense into water droplets, which fall to the ground as rain (Wetzel [3], Brutsaert [9]).

The volume of rain falling on a square meter (m^2) of land is called precipitation. According to the data from SEMARNAT-CNA [10], in Mexico it rains a volume of 1,489 km^3 (cubic kilometers) per year (V = the volume of the total annual rainfall = 1.489×10^{12} liters yr^{-1}), which would form a swimming pool of 0.74 m depth if it were distributed throughout the national territory (Table 1).

Table 1: Hydrologic balance of Mexico.

#	Compartment	Volume (km^3)	% of total
1	Territorial precipitation	1,488.819	100
2	Evapotranspiration	1,065.270	71.6
3	Infiltration	92.625	6.2
4	Territorial runoff	330.924	22.2
5	Importation	48.381	
6	Concession (-)	0.432	
7	Total runoff (4+5-6)	37.873	
8	Available (3+7)	471.498	

Of this Vp, 71.6% evaporates again (1,065 km^3), and 6.2% (92.6 km^3) infiltrates into the subsurface, leaving nearly 471.5 km^3 of liquid water.

The Vp is roughly a tenth of the rain throughout North America and a twentieth of the rain in South America (Banderas [11]). As will be seen below, this difference emerges in the North-South gradient of the distribution of rainfall over Mexico. One part falls into the sea and one on land, either domestic or foreign (importation and concession). This can accumulate in puddles, ponds and lakes or can drain on the surface to form streams, which then fuse to form rivers of different sizes depending on the area of the catchment and the intensity of the rain.

Groundwater constitutes the largest volume of water used in the country, especially in the north central region, covering almost 70% of the country and where precipitation is extremely reduced by continental effect (Table 2).

Table 2: Comparison of rainfall in several areas.

# Basin	Name	Area (km^2)	Rainfall (m)	Climate	Population ($x10^6$)
6	Baja Calif SE	11,541	0.002	Very dry	1
8	Sonora N	61,340	0.002	Very dry	1
9	Sonora S	139,169	0.01	Very dry	1.5
12	Lerma-Santiago	132,724	0.207	Subhumid	20
18	Balsas	118,097	0.311	Subhumid	10
29	Coatzacoalcos	30,173	1.079	Wet	8
30	Grijalva-Usum	102,317	0.919	Subhumid	5
31	Yucatán W	25,406	0.958	Subhumid	2

Most Mexican rivers flow to the sea and along their banks have some type of damming. The volume of water dammed is close to 159 km^3, which represents 11% of the total precipitation. Finally, the sun again evaporates seawater which is somewhat stagnant in form, and vegetation transpires elsewhere. Both are incorporated into the clouds, completing the water cycle.

3.2 The price of water based on management costs

Once nature has given this volume of water, people access it to satisfy their needs. The National Water Commission (CONAGUA) manages the water in Mexico, (Diario Oficial de la Federación [12]), including collection, measurement, distribution, pollution assessment, treatment, arbitration, for which it receives an annual budget that is increasing due to the higher demand for this resource. In 2003 the budget was 829.5 million USD. In 2013 it jumped up to 2,733.3 million USD and for 2014 was approximately 3,600 million USD ($3.6x10^9$ USD per year), of this most comes from government subsidies and a quarter from the collection of the service fee (Solís [4]).

From the available volume (Table 1), 83 km^3 are franchised, which must include the 27 km^3 extracted from the subsoil (northern aquifers are overexploited) and the 56 km^3 of surface water. Thus, the CONAGUA is involved in the administration of these 83 km^3 plus 150 km^3 stored in dams and about 11 km^3 in lakes, in total 244 km^3, which are a little over half (52%) of the volume of water available, representing 16.4% of the total precipitation falling in the country.

Dividing the budget of the CONAGUA by the volume of water managed, during 2014 Mexicans paid for administrative expenses:

$$(3.6\text{x}10^9 \text{ USD yr}^{-1})/(244\text{x}10^9\text{m}^3\text{yr}^{-1}) = 0.0147 \text{ USD m}^{-3} \quad (1)$$

The volume of the lakes can be eliminated because their level depends on climatic variations and no management. so this payment rises to 0.0154 USD m^{-3}. Considering only the water concessions, this payment rises to 0.043 USD m^{-3}. Apparently it is a low price, but the water itself costs nothing.

Table 2 shows the uneven distribution of rainfall. The fourth column represents the depth of the pool to be formed if the annual precipitation was accumulated. This figure, multiplied by 1000 liters of annual rainfall, gives the square meterage of land. Dry areas of Baja California and Sonora have a rainfall of 2 liters per m^2 per year and can go several years without precipitation. It rains more in the south of Sonora, i.e. 10 liters. Even more rain falls in Guanajuato and Chilpancingo, 207 and 311 liters, respectively. In the Southeast rainfall may amount to 1000 liters or more.

3.3 The price of municipal water

The CONAGUA provides drinking water to municipal water systems in metropolitan areas of the country, which offer services to the public per cubic meter. Table 3 shows a comparison of the prices paid in some cities (SEMARNAT-CNA [10]). The cost is based on single-family consumption and cities are ordered from north to south.

Table 3: Prices of water per city (m^3).

City	Price of water USD m^{-3}	Unsubsidized price USD m^{-3}
Tijuana	1	
Hermosillo	0.4	
Aguascalientes	1	
Naucalpan	0.133	
Federal District	0.16	1.33
Tabasco	0.057	
Campeche	0.106	

Comparing Tables 2 and 3 will demonstrate that where water is scarce the price is higher and, therefore, is subject to the law of supply and demand. If the area is dry and the price is low this is because water comes from groundwater or a nearby dam. In contrast, in the areas of Chiapas and Coatzacoalcos, the law of supply and demand is canceled, especially during the hurricane season. Here, the problem is not bringing water to where it is needed, but containing it to prevent flooding and, if necessary, removing it from towns, streets and houses.

The scheme of water heterogeneity and social contrast becomes more dramatic when comparing the 13 hydrological regions of the country defined by the

CONAGUA for administration. In Zone II, called the Southern Border, there is greater availability of both the total and per capita water, with 157,754 x10^6 m^3 $year^{-1}$ and 24,043 m^3 hab^{-1} yr^{-1}. In Zone XIII, called the Basin of Mexico, located in the Mexican plateau, availability is low, with 3,514 x 10^6 m^3 yr^{-1} and 165 m^3 hab^{-1} yr^{-1}, respectively. Note that those who should pay for the available volume live in an area of lower income per capita (Southern Border), and those who should pay less for the available volume are in the area of highest income per capita (Basin of Mexico).

The Basin of Mexico is a peculiar case. It occupies 5% of the territory and accounts for 33% of the population. Here, the law of supply and demand is nullified by the authorities themselves, which artificially increase the supply by importing water from other basins at high operating costs. These are not paid by the consumer, but through government subsidy. This justifies such a management scheme arguing that Mexico City provides 42% of national GDP. But it should ask: for how much longer?

4 The intrinsic value of water: a proposal

4.1 The energy investment from the sun

The sun does all the work to evaporate and circulate the water in the hydrosphere in the manner already described. There are tools to measure the amount of solar energy reaching the Earth and how it is distributed in the hydrological cycle. The annual average energy incident to the outer surface of the atmosphere is 1.92 calories per square centimeter per minute (1.92 cal cm^2 min^{-1}), or 29.6 MJ m^{-2} day^{-1} (Mega Joule per square meter per day) (Nobel [8]).

This amount is called the *solar constant* that, due to the sphericity of the earth, is less at the poles and higher in Ecuador. Once entering the atmosphere, this energy is attenuated by gases and dust from the air and only 58% reaches the ground (17 MJ m^{-2} day^{-1}). Only a fraction of the latter is absorbed by water.

In general, we can say that an area located 25 degrees north latitude (such as north-central Mexico) has an approximate average ambient temperature of 25°C. Evaporating a kilo of water at this temperature requires 2.44 MJ (Qev = 2.44 MJ kg^{-1}). The density of water is unitary: one kilo has the volume of one liter. So to evaporate the water precipitated in the country in a year would involve absorbing an amount of energy equal to:

$$Qt = (Qev)\ (Vp) = (2.44\ MJ\ kg^{-1})\ (1.489x10^{12}\ kg\ yr^{-1}) = 3.63x10^{12}\ MJ\ yr^{-1} \quad (2)$$

The Qev decreases with increasing temperature, so that global warming promises greater evaporated water content in the atmosphere and, consequently, more rain. To make this explanation more accessible, the MJ should be transformed into a more useful unit called a Watt. One Watt = one Joule per second (1W = 1J s^{-1}). Conversely, 1MJ = 0.2778 kW per hour (Nobel [8]). The kW h is the unit of measurement of electrical services which appears on electricity bills for Mexican homes. So the Qt in kW h of precipitation in Mexico was:

$$Qt = (3.63x10^{12}\ MJ\ yr^{-1})\ (0.2778\ kW\ h\ MJ^{-1}) = 1.01\ X10^{12}\ kW\ h\ yr^{-1} \quad (3)$$

In other words, this is the energy that the sun provided to the country to distill the water that comes in the form of clean rain, with no contaminants or salts (except in restricted urban and industrial areas) and retaining all the potential uses you want to put it to, including hydropower generation.

It is important to note that these calculations were made on average amounts of energy, temperature and latitude. They can be refined considering precise data from the network of stations and satellites of the National Weather Service, but it also should be emphasized that this refinement will only affect the roots (probably high) and not the orders of magnitude.

4.2 Conversion of currency investment in solar energy

Solar energy is converted into money as follows: in Mexico, electricity costs the consumer 0.054 USD for the first 75 kW h; 0.066 for the following 65 kW h; and 0.1932 for each additional kW h. Whether or not the responsible unit (Comisión Federal de Electricidad, CFE) sets a fair price is not the subject of this article, but it can be used to attach an intrinsic price to water. Which of these prices must be considered for our financial calculations?

The sun is not involved in pricing, but certainly it brings much more energy than the first 75 or 65 kW h rate quoted to evaporate and transport water then precipitated in the country. Therefore, in fairness, you would have to pay 0.1932 a kW h. That is:

$$SF = (1.01 \times 10^{12} \text{ kW h year}^{-1})(0.1932 \text{ kW h}) = 19.51 \times 10^{10} \text{ USD yr}^{-1} \qquad (4)$$

If we take the lower rate, one would have to pay 5.45×10^{10} USD year^{-1}. Any of these quantities can be called solar capital financing, or solar financing (SF). To give an idea of the importance of these capital budgets, CONAGUA is between one and two orders of magnitude smaller than the solar financing (Eq. 4). In addition, CONAGUA administered only 16.4% of Vp (1,489 km^3) which is precipitated in the country.

It should be noted that the administration does not include evaporated (71.6%) volume, which is of fundamental importance because it provides environmental services such as rain potential, climate regulator, and a shield against ultraviolet radiation, and is a promoter of photosynthesis and plant growth and animal (primary and secondary) production.

To calculate the intrinsic value of water (IVW) following this reasoning, let us give a price for each cubic meter of water produced by the sun, simply dividing the solar financing (SF) between the precipitate volume (Vp) in cubic meters:

$$IVW = (19.51 \times 10^{10} \text{ USD yr}^{-1}) / (1.489 \times 10^{12} \text{ m}^3 \text{ yr}^{-1}) = 0.131 \text{ USD m}^{-3} \qquad (5)$$

This amount can be rounded to 0.13 USD m^{-3} of water. Applying a social focus and taking the lower price of kW h, we obtain:

$$IVW = (5.45 \times 10^{10} \text{ USD yr}^{-1}) / (1.489 \times 10^{12} \text{ m}^3 \text{ yr}^{-1}) = 0.036 \text{ USD m}^{-3} \qquad (6)$$

For the purposes of this article, the latter is the value of water in its pristine and totipotential state, obtained by distillation effected by natural solar radiation incident to the sea primarily, in the natural physiographic conditions of this portion of the Earth called Mexico.

5 Final considerations

Considering environmental grounds, a proposal to establish an intrinsic value for water (IVW) has been developed, based mainly on the factors involved in the water cycle on Earth, established since the beginning of its geological history and thanks to which life exists on the planet.

From the point of view of the authors, the IVW thus calculated is exempt from the law of supply and demand and, therefore, free from speculation, their calculations are based on the general need and the particular ambition. Therefore, the IVW should be included in the price per unit volume that is offered to the public, regardless of the use made or administration costs.

This means that no states of the world are exempt from paying the IVW per unit of the volume which precipitates on their territory, since they will be paying no extra charge, the environmental service of water, i.e. water evaporated naturally besides running freely through the rivers and that bypasses meters of any kind or dependency, whether official or private.

The money collected should be called IVW solar financing and would go towards projects of scientific and technological research, as well as works and actions for the conservation of water volume and quality in the natural ecosystems, especially to cushion the effects of climate change (Smith [13]).

The volumes considered in the previous paragraph do not pass through the hands of man only as numbers (it can be called wild water). But each unit volume managed by man shall include the IVW, administration costs, construction, operation and maintenance of water service, whether for those who are under conditions of scarcity in arid areas, or for those who are in conditions of excess in humid areas.

The money collected from non-wild water in both dry and wet areas should be addressed to jobs diametrically opposed to the purposes of water management. In dry areas the collection, storage, treatment and recycling of water is a priority. In the humid zones containment and rapid evacuation is more important. Moreover, global warming will increase precipitation where it is abundant and reduce it where it is currently scarce.

From the author´s point of view, the above fee should be the same regardless of the area, since the difference between areas lies in the most expensive phase of the process. In the humid areas this occurs before (containment and evacuation) and in arid areas, after (treatment and recycling) the water passes through the hands, machines, animals, plants or any production process of man (Banderas and González [14]).

The appropriateness of the price of a kW h of electricity as a basis for this calculation must be analyzed, because you have to consider that it not only includes the costs of generation, distribution and maintenance of the network, but also represents a business (of unknown dimension) for the operator, equivalent to adding an aberration of unknown size to the IVW.

The price of a kW h defined by the CFE (Comisión Federal de Electricidad) is applied because it is more accessible and stable; however, the lower rate should be applied. The price of the work produced by the energy of hydrocarbons cannot be used because it is subject to continuous increases in the country and abrupt fluctuations in the international market.

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