**Journal of Energy and Natural Resources**
2019; 8(1): 30-36
http://www.sciencepublishinggroup.com/j/jenr
doi: 10.11648/j.jenr.20190801.15
ISSN: 2330-7366 (Print); ISSN: 2330-7404 (Online)

# Using Meteorological Data to Adjust Water-Pricing of Urban Resident Households

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**To cite this article:**

Juan Zhao, Xingmin Mu, Wenbing Shi, Mei Ou. Using Meteorological Data to Adjust Water-Pricing of Urban Resident Households. *Journal of Energy and Natural Resources*. Vol. 8, No. 1, 2019, pp. 30-36. doi: 10.11648/j.jenr.20190801.15

**Received**: January 20, 2019; **Accepted**: April 2, 2019; **Published**: April 28, 2019

**Abstract:** In this paper, a dynamic method is presented for setting the price of urban residential water. Using a model called Seasonal Water Pricing (SWP); urban residential water pricing was set by taking into account the fact that some of the characteristics of temperature and precipitation may also influence residential water supply levels. In this work, an SWP model was adopted and used to estimate correction coefficients for urban residential water prices. The adjusted cost of water was < 3% of the disposable per capita income of customers. Thus, this work offers a basis for reforming water resource pricing in China.

**Keywords:** Water Prices, SWP Model, Temperature, Precipitation, Adjusted Water Pricing, Xi'an

## 1. Introduction

This Water shortage crises have always attracted great attention in human history, especially in recent decades [1, 18]. The current water resource crisis in China has been building since the 20th century, and there are several striking features of the water resource situation in modern China. First, although water is abundant by many measures, the per capita amount is too small. The water supply suffers from uneven distribution in space and time, and there are frequent extremes (droughts and floods). At human scale, there are obvious contradictions between water supply and demand. This all means that uneven distribution, and mismatch in supply of, and demand for, water resources in China is expected to intensify in the 21st century [37].

To ensure efficient use and allocation of water resources, the Chinese government has adopted water price leveraging to alleviate the contradictions between the supply and demand of water, and to promote water conservation. It has been proven that raising the price of water is an effective tool for the protection of water resources [16]. Water price signals affect the market shares of different water appliances, as well as the water usage in households, ultimately improving water use efficiency [5]. The present low water price leads to excessive waste of water. Promoting a higher water price is an important approach for maintaining water services. This involves continuous implementation and maintenance of hydraulic engineering infrastructure, and realization of sustainable development policies in terms of urban water resources and economy [13-14]. Chinese style ecological modernization should pay more attention to the institutional dimensions of natural resource pricing policies, if it is to profit from the theoretical advantages of economic approaches in urban water management [36].

There has been an analysis of the relative merits of market-based and prescriptive approaches for water conservation for economies where prices have rarely been used for the allocation of scarce supplies. The analysis emphasizes the emerging theoretical and empirical evidence that using price to manage water demand is more efficient than implementing conservation programs not based on price [29-30]. In practice, actual water pricing is underestimated by most utilities because the prices are based on average embedded utility, calculated using historical accounting costs rather than effective economic costs.

Researchers have used several methods aimed at determining water pricing. These water pricing methods can be divided into three categories. The first is based on production costs: for example, the average cost method or the marginal cost method [2, 9-10, 28]. The second pricing method is based on all costs: for example, the shadow price method or full cost pricing [4, 7-8, 12, 31, 38]. The third method is based on operability: for example, using two-part tariff pricing and multistep water pricing [20, 27, 33]. These methods each have their respective merits and demerits (Table 1).

***Table 1.*** *Advantages and disadvantages associated with different water pricing methods.*

| Pricing method | | Advantage | Disadvantage |
|---|---|---|---|
| Based on production cost | average cost method | makes up for the operation cost to provide enough income | considers only the production cost, and does not consider other costs |
| | marginal cost method | can restrain the consumption of water resources in case of increasing marginal costs | |
| Based on all costs | shadow price method | reflects the relationship between water resources and the overall benefit | Considering the water environment quality, Regardless of the drainage |
| | full cost pricing | Shows various costs for development and utilization of water resources | |
| Based on operability | two-part tariff pricing | ensures stable income for water agencies and promotes optimized allocation of water resources | does not consider all costs and environmental degradation |
| | Multistep water pricing | makes up for the losses from single pricing | |

In the methods mentioned above, the water prices are static. This causes stress related to increasing water demand and water conservation practices. Moreover, these pricing methods do not consider natural factors such as precipitation and temperature that lead to seasonal variation in the water supply.

Global climate change associated with rising atmospheric concentrations of greenhouse gases are altering regional temperature and precipitation patterns. Such changes threaten the availability (or at least the consistency) of water supply to rapidly growing Third World cities, many of which have already been experiencing severe water supply deficiencies. Many studies have shown the impacts of climate change on water resource availability [3, 6, 11, 15, 17, 21, 24-25, 32].

The shifting patterns of precipitation and evaporation show huge variation over seasons and years, which invariably leads to periods of drought and incidental floods in many areas. It is likely that anthropogenic climate change will significantly increase human exposure to droughts and floods. It will also alter seasonal patterns of water availability and affect the water quality and health of aquatic ecosystems. These changes have serious implications for human social and economic wellbeing [17].

Therefore, there is an urgent need to develop water trading regimes that are ecologically beneficial, sustainable; and that facilitate efficient allocation of water for all uses (including ecosystem services). Meanwhile, the issue of long-term qualitative changes in water use must also be addressed with new tools and approaches.

In this paper, an approach is proposed by which to adjust the market pricing of water resources based on atmospheric conditions, and to improve resource efficiency in the context of a market economy. According to this method, current water pricing should also consider the impact of factors such as temperature and precipitation. The proposed method provides for seasonal pricing and provides insights into how the distributional effects of this pricing system could be used to influence future pricing decisions. The SWP method adopts a dynamic method to calculate current water price, which provides a new idea for sustainable water price reform. This model is simple and feasible, which can improve people's water-saving awareness and alleviate the contradiction of water shortage.

# 2. Main Body

### *2.1. Methods: The SWP Model*

Precipitation and temperature are the two main factors that affect the quantity of water available for water supply. Starting from a case study in Belgrade, a Seasonal Water Pricing (SWP) model was developed that is dependent upon seasonal conditions and variability [26].

The SWP model is a tool for making adjustments to water resource pricing. The SWP is not a new method for calculating prices, but rather a method for analysing water resource prices as affected by natural conditions. Local parameters such as precipitation and temperature affect the water supply; accordingly, the SWP model adopts a localized, place-based, dynamic approach for calculating the current water prices. A seasonal tariff correction factor was also introduced in this model.

Water pricing methods should consider and provide for factors such as restraining people by economic means, from misusing and wasting scarce resources. In addition, an effective pricing method should consider and provide for changes related to season and for changes in the capacity for social adaptation [22]. In a market economy, commodity prices are expected to reflect their scarcity and to be an accurate measure of their scarcity. Water supply goes through natural seasonal changes; however, this is not reflected in government (or private) water pricing policies. According to the Price Theory in economics, the pricing mechanism adjusts the production and consumption of goods towards rational allocation; if given a chance to operate.

The basic principle of the proposed model illustrates the sensitivity of water resources prices to temperature and precipitation. The seasonally adjusted water price takes the following form (Eq. 1):

$$SWP = wP * \tau \quad (1)$$

where SWP is the seasonally adjusted water price, wP is the regular water price determined by a public water supply company, τ is the correction factor applied from May to September.

Here, the decision variable of the system, τ, can be calculated using the equation below (Eq. 2).

$$\tau = 1 + \left[\frac{MAt - LRAt}{LRAt} + \frac{LRTp - MTp}{LRTp}\right]/2 \quad (2)$$

where MAt is the average temperature for a certain month, in °C, LRAt is the long-term average temperature (normal temperature) for a given area, MTp is the total precipitation for a certain month, in mm. LRTp is long-term total precipitation (normal precipitation) for a given area, $MAt - LRAt$ shows a warm temperature effect, and $LRTp - MTp$ shows a low precipitation effect.

This approach ensures that the water supply process and quantity will be affected by temperature and precipitation. In warm weather, people take more showers, do laundry more frequently, water their garden more often, and use swimming pools more regularly; therefore, the use of water will increase. Owing to the higher demand on the water supply in such a scenario, the water prices should also increase. Conversely, precipitation and cold weather reduce the demand for water. As precipitation increases, the quantity of water provided by nature is greater (perhaps enough), and the regular cost of water would be the basic cost of supplying the water. By considering these factors, the water prices can be adjusted to cover the actual current cost (i.e., a ‘fair’ market price) of the water supplied. Using these prices to manage demand via market mechanisms, makes the water supply more sustainable (and the water market more efficient).

The use of the SWP model to adjust the water price is expected to spread awareness regarding the rational use and protection of water resources, in addition to increasing the financial performance of the water sector in general.

For instance, especially for periods with lower precipitation than normal, government (and private) water providers will face higher water supply costs. However, if the government stops supplying water to some high-demand commercial users to conserve the water supply, revenue declines. In other words, prudent management of the water supply would cause a decline in the income of water suppliers (government or business).

However, under the SWP model, if a drought occurs, water prices would be raised accordingly, and some activities involving water would be reduced (for example: swimming or washing cars). The SWP model can only prove effective if consumers clearly understand the water pricing rules. As long as consumers know how to calculate water prices in the dry season, they will have the chance to respond reasonably to varying seasonal prices. Thus, the basic premise underlying the efficient use of the SWP model is that water consumers should have a full understanding of the water pricing rules.

In China, the SWP model can easily be explained to consumers because the variations in water pricing depend on two exogenous parameters (i.e. precipitation and temperature), which are officially monitored by the China Meteorological Administration. Based on the official forecasts of precipitation and temperature in the coming year, the trend of change in the water prices could be predicted (perhaps with estimates provided to consumers season by season).

### *2.2. Study Area*

Xi’an City was the target study area of this research. Xi'an is the capital of Shaanxi Province, located in the southern part of the Guanzhong Plain. It lies between the latitudes of 33°39' 30" to 34°45' 00" N and longitudes of 107°39' 00" to 109°49' 00" E. Xi'an City covers an area of 1066 $km^2$, and has a population of more than 8,300,000. With the Qinling Mountains to the south and the Weihe River to the north, it is in a favourable geographical location surrounded by water and hills. It has a semi-moist monsoon climate and there is clear distinction between the four seasons. The Wei River is the main watercourse. It runs from west to east and is fed by dozens of tributaries originating from the Qin Mountains. The Weihe River runs for 150 km, and through Xi'an City (Figure 1), where the annual runoff reaches 25×108 $m^3$.

Approximately 70% of the raw water used in the area is acquired from surface runoff, with the remaining 30% being supplied from deep underground reservoirs via deep wells [34]. The city also has some wastewater treatment facilities.

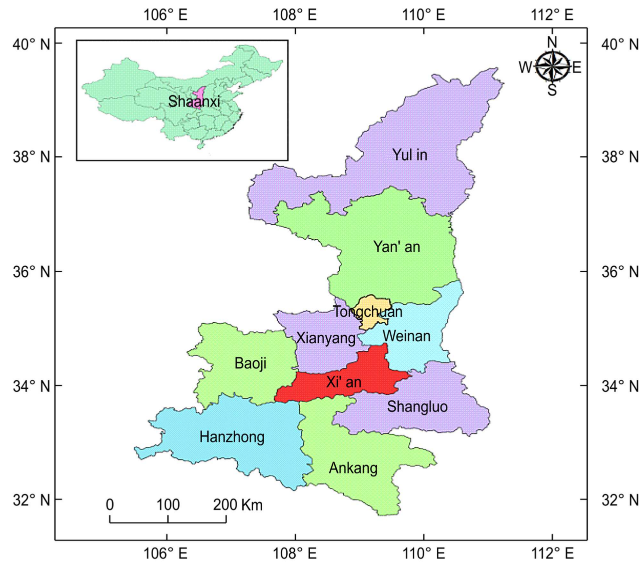


***Figure 1.*** *Xi'an.*

### *2.3. Data*

The SWP model assumes that actual water pricing is scientific and rational. In order to test the model, the monthly precipitation and temperature data for the city of Xi’an for all months of a year (from 2001 to 2013) were analysed. Measurements of precipitation and temperature were compared with averages of long-term data on precipitation and temperature. Monthly precipitation and temperature data were collected by local meteorological stations. The long-term monthly average temperature data is the "average" value of 50 years yearly average temperature (1951–2000), and long-term monthly total precipitation data is the "average" value of 50 years yearly average precipitation (1951–2000).

The pricing policy of the government for Xi'an is based on a uniform rate system, with some differentiation based on consumer types (Table 2). From 2001 to 2013, the actual water prices have varied: the water pricing method has been changed three times. In other words, during the past 14 years, four water pricing standards have been used in Xi 'an City.

***Table 2.*** *The prices of water services in Xi'an.*

| Consumer groups | Water supply price | | | |
|---|---|---|---|---|
| | Before 2004.5 | 2004.5.1-2005.10.1 | 2005.10.1-2007.4.1 | 2007.4.1-2014 |
| Households water (include: households, charity house, old people's home, community residents committee service facilities, and all kinds of schools, kinderpower) | 1.50 | 1.95 | 2.45 | 2.9 ¥/$m^3$ |

http://wjj.xa.gov.cn/ptl/def/def/index_1285_3892_ci_trid_25263.html

### *2.4. Results and Discussion*

Values of the correction factor τ are shown in Table 3. When τ > 1, the predicated data of monthly precipitation is more than the average data of the past 50 years, at the same time, the predicated data of monthly temperature in average is less than the one collected over the past 50 years. When τ = 1, the predicted monthly precipitation and temperature are close to the average of the past 50 years. When τ < 1, the predicted monthly precipitation is lower than the average of the past 50 years, at the same time, the predicted monthly temperature on average is higher than the one based on data collected over the past 50 years.

***Table 3.*** *Values of correction factors.*

| τ | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | -0.81 | 1.73 | 1.75 | 1.07 | 1.48 | 1.08 | 1.07 | 1.32 | 1.11 | 1.00 | 1.54 | -0.18 |
| 2002 | -2.44 | 2.16 | 1.51 | 1.44 | 0.79 | 0.57 | 1.51 | 1.28 | 1.17 | 1.26 | 1.42 | -0.56 |
| 2003 | -0.51 | 1.07 | 1.41 | 0.96 | 1.14 | 1.12 | 0.83 | 0.41 | 0.45 | 0.27 | 0.89 | 1.60 |
| 2004 | -0.31 | 0.92 | 1.10 | 1.46 | 1.31 | 0.46 | 1.23 | 1.28 | 0.98 | 1.28 | 0.86 | 0.73 |
| 2005 | 1.00 | 0.93 | 1.53 | 1.46 | 1.21 | 0.97 | 1.30 | 0.66 | 1.00 | 0.50 | 1.69 | 1.35 |
| 2006 | 0.56 | 0.82 | 1.63 | 1.10 | 1.11 | 0.74 | 1.38 | 1.15 | 1.07 | 1.31 | 1.56 | 1.75 |
| 2007 | -1.01 | 2.37 | 0.99 | 1.59 | 1.37 | 0.96 | 0.22 | 0.48 | 1.20 | 0.83 | 1.65 | 2.04 |
| 2008 | 1.00 | 0.99 | 1.38 | 1.00 | 1.41 | 0.99 | 1.09 | 0.95 | 1.08 | 0.92 | 1.43 | 2.66 |
| 2009 | 1.23 | 1.17 | 1.07 | 1.41 | 0.59 | 1.30 | 1.10 | 0.80 | 1.08 | 1.40 | 0.57 | 0.75 |
| 2010 | 0.38 | 1.27 | 1.23 | 0.99 | 1.18 | 1.29 | 0.98 | 0.52 | 1.16 | 1.15 | 1.47 | 2.65 |
| 2011 | 3.15 | 1.03 | 1.36 | 1.43 | 0.84 | 1.23 | 1.12 | 0.94 | -0.05 | 1.17 | 0.52 | 1.24 |
| 2012 | 1.19 | 1.39 | 1.26 | 1.48 | 0.97 | 1.35 | 1.25 | 0.96 | 1.01 | 1.41 | 1.26 | 1.01 |
| 2013 | 0.31 | 1.28 | 1.71 | 1.36 | 0.38 | 1.31 | 0.92 | 1.36 | 1.45 | 1.49 | 1.05 | 2.06 |

According to the model, the amendment factors are included in the calculation only if the correction factor τ is greater than '1', and water pricing is to be adjusted according to them. If τ is equal to or lesser than '1', the amendment factor is '1', and the regular water price is imposed on all customer groups. If the described price setting rule was in operation during the period 2001–2013, the amendment factors would be as in Table 4. During the period from December to February, which is affected by meteorological factors, the effect of the amendment factors is more pronounced.

***Table 4.*** *Adjustment factors.*

| | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 1.00 | 1.73 | 1.75 | 1.07 | 1.48 | 1.08 | 1.07 | 1.32 | 1.11 | 1.00 | 1.54 | 1.00 |
| 2002 | 1.00 | 2.16 | 1.51 | 1.44 | 1.00 | 1.00 | 1.51 | 1.28 | 1.17 | 1.26 | 1.42 | 1.00 |
| 2003 | 1.00 | 1.07 | 1.41 | 1.00 | 1.14 | 1.12 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.60 |
| 2004 | 1.00 | 1.00 | 1.10 | 1.46 | 1.31 | 1.00 | 1.23 | 1.28 | 1.00 | 1.28 | 1.00 | 1.00 |
| 2005 | 1.00 | 1.00 | 1.53 | 1.46 | 1.21 | 1.00 | 1.30 | 1.00 | 1.00 | 1.00 | 1.69 | 1.35 |
| 2006 | 1.00 | 1.00 | 1.63 | 1.10 | 1.11 | 1.00 | 1.38 | 1.15 | 1.07 | 1.31 | 1.56 | 1.75 |
| 2007 | 1.00 | 2.37 | 1.00 | 1.59 | 1.37 | 1.00 | 1.00 | 1.00 | 1.20 | 1.00 | 1.65 | 2.04 |
| 2008 | 1.00 | 1.00 | 1.38 | 1.00 | 1.41 | 1.00 | 1.09 | 1.00 | 1.08 | 1.00 | 1.43 | 2.66 |
| 2009 | 1.23 | 1.17 | 1.07 | 1.41 | 1.00 | 1.30 | 1.10 | 1.00 | 1.08 | 1.40 | 1.00 | 1.00 |
| 2010 | 1.00 | 1.27 | 1.23 | 1.00 | 1.18 | 1.29 | 1.00 | 1.00 | 1.16 | 1.15 | 1.47 | 2.65 |
| 2011 | 3.15 | 1.03 | 1.36 | 1.43 | 1.00 | 1.23 | 1.12 | 1.00 | 1.00 | 1.17 | 1.00 | 1.24 |
| 2012 | 1.19 | 1.39 | 1.26 | 1.48 | 1.00 | 1.35 | 1.25 | 1.00 | 1.01 | 1.41 | 1.26 | 1.01 |
| 2013 | 1.00 | 1.28 | 1.71 | 1.36 | 1.00 | 1.31 | 1.00 | 1.36 | 1.45 | 1.49 | 1.05 | 2.06 |

Table 5 displays the adjusted household water prices using the SWP model, where some data has been highlighted because the actual water price is different. The given model is a reasonably adequate representation of water demand in Xi'an City.

***Table 5.*** *Adjusted household water prices for 2001–2013 period in CNY/m³.*

| | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 1.50 | 2.59 | 2.63 | 1.60 | 2.23 | 1.62 | 1.60 | 1.98 | 1.67 | 1.50 | 2.31 | 1.50 |
| 2002 | 1.50 | 3.24 | 2.27 | 2.16 | 1.50 | 1.50 | 2.27 | 1.92 | 1.76 | 1.89 | 2.14 | 1.50 |
| 2003 | 1.50 | 1.61 | 2.12 | 1.50 | 1.71 | 1.68 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 2.39 |
| 2004 | 1.50 | 1.50 | 1.65 | 2.20 | *2.56* | *1.95* | *2.39* | *2.50* | *1.95* | *2.49* | *1.95* | *1.95* |
| 2005 | *1.95* | *1.95* | *2.98* | *2.85* | *2.36* | *1.95* | *2.54* | *1.95* | *1.96* | 2.45 | 4.13 | 3.31 |
| 2006 | 2.45 | 2.45 | 4.00 | 2.70 | 2.72 | 2.45 | 3.39 | 2.81 | 2.63 | 3.20 | 3.83 | 4.29 |
| 2007 | 2.45 | 5.79 | 2.45 | 4.61 | 3.98 | 2.90 | 2.90 | 2.90 | 3.49 | 2.90 | 4.79 | 5.91 |
| 2008 | 2.90 | 2.90 | 4.02 | 2.90 | 4.09 | 2.90 | 3.18 | 2.90 | 3.13 | 2.90 | 4.15 | 7.71 |
| 2009 | 3.58 | 3.39 | 3.10 | 4.08 | 2.90 | 3.78 | 3.19 | 2.90 | 3.14 | 4.05 | 2.90 | 2.90 |
| 2010 | 2.90 | 3.68 | 3.57 | 2.90 | 3.41 | 3.74 | 2.90 | 2.90 | 3.37 | 3.35 | 4.27 | 7.69 |
| 2011 | 9.12 | 2.97 | 3.95 | 4.15 | 2.90 | 3.57 | 3.24 | 2.90 | 2.90 | 3.40 | 2.90 | 3.58 |
| 2012 | 3.46 | 4.03 | 3.65 | 4.30 | 2.90 | 3.92 | 3.62 | 2.90 | 2.93 | 4.10 | 3.65 | 2.93 |
| 2013 | 2.90 | 3.71 | 4.96 | 3.95 | 2.90 | 3.79 | 2.90 | 3.95 | 4.22 | 4.32 | 3.04 | 5.96 |

A comparison between adjusted and actual water prices makes it clear that the increase in water prices would have been considerably higher if the SWP model had been applied, especially during the hot, dry years (e.g. 2001, 2002, 2006, and 2012). In the year 2011, for example, the water prices for January, March, April, June, July, October and December would have been higher than the original price; the regular water price would be applicable in the remaining months. The highest increases for households would have been applicable in the months of January 2011 (215%), December 2008 (166%), December 2010 (165%) and December 2013 (106%) (Table 6). In all other months, the price increases would have been much lower. Also, in certain months, such as January, May and July 2013, the prices would have remained unchanged.

***Table 6.*** *Social sustainability of adjusted household water prices.*

| | Household prices (TSP) | Average household consumption | Household disposable income (CNY) | Monthly water payment (b) | Bearing index (b/CNY) |
|---|---|---|---|---|---|
| Feb. 2002 | 3.24 | 12.96 | 7184 | 155.52 | 2.16% |
| Mar. 2005 | 2.98 | 11.92 | 9628 | 143.04 | 1.49% |
| Dec. 2006 | 4.29 | 17.16 | 10905 | 205.92 | 1.89% |
| Jan. 2011 | 9.12 | 36.48 | 25981 | 437.6 | 1.68% |

Prior to April 2004, the actual water price was 1.50 CNY/m$^3$. During this period, the highest adjusted household water price was 3.24 CNY/m$^3$, applicable in February 2002. From 1 May 2004 to 30 September 2005, the actual water price was 1.95 CNY/m$^3$. During this period, the highest adjusted household water price was 2.98 CNY/m$^3$, applicable in March 2005. From 1 October 2005 to 31 March 2007, the actual water price was 2.45 CNY/m$^3$. During this period, the highest adjusted household water price was 4.29 CNY/m$^3$, applicable in December 2006. After 1 April 2007, the actual water price was 2.90 CNY/m$^3$. During this period, the highest adjusted household water price was 9.12 CNY/m$^3$, applicable in January 2011.

Under the SWP pricing model, household water demand is calculated based on a standard of 4 m$^3$ per person per day. In all cases, the cost of water is much lower than the 3% in urban disposable incomes threshold proposed by the World Bank, or the 2.5% in urban disposable incomes threshold proposed by the Ministry of Housing and Urban-Rural Development of the People's Republic of China. Adjusted water prices are also perceived to be socially acceptable. Residents could comfortably afford to pay much more than is currently being charged for water, so the water prices could be raised substantially. Therefore, using the adjusted prices for comparison, the regular water prices appear to be too low. Note also, that compared to other water pricing models [4], the proposed model is a very simple one, with a low demand for information input.

It is indeed true that climatic variation linked to global warming exists. This variation is increasing the frequency of occurrence of short-duration precipitation events, as well as the opposite, long-duration precipitation events [23, 35, 39]. This is the main reason that water pricing should fluctuate more within a year. In contrast, the current water prices imposed by the government (the Xi'an Price Bureau) are far lower than the adjusted prices proposed in this paper. At present, the adjusted water price for residential use is higher than that for most other sectors. If the government should increase the market price of water across all sectors, according to the adjusted water price model, perhaps the use of water could be made more reasonable and economical to residents.

For pricing to be effective, the current price could be set as the floor price during water trading. The proposed method could be used to calculate water price adjustments based on natural factors that affect the water supply. This would ensure water price stability, as well as take into account reasonably, the interests of both the supply and demand sides of water provision.

# 3. Conclusion

In this study, the SWP model was applied to provide an adjusted water pricing approach to calculate variable prices for urban water resources. It accommodates the fact that water pricing is not only affected by demand, but also is based on supply. The steps used with this method can be summarized as follows. First, the basic assumption here is that the water price calculations are scientific, reasonable and understood by society. Second, the correlation coefficients between meteorological factors and water pricing are calculated. Then the adjusted prices are calculated according to the correlation coefficients. Last, the feasibility of applying this method is evaluated by checking the bearing capacity of the new water rates (i.e. can consumers pay higher rates).

For the case study, the prices were adjusted using atmospheric data for Xi'an City over the period 2001–2013. During the period affected by meteorological factors, the amendment factors do not remain static. In particular, they are more intense in winter (December to February). The study revealed that water prices would be higher during dry seasons and lower in wet ones.

If adjusted water prices were implemented, residents would spend much more for water than at present, but even the extremes would be much lower than the 3% threshold proposed by the World Bank. Adjusted water prices are also perceived to be socially acceptable.

Considering the dynamic factors that affect the supply, such as precipitation and temperature, different prices could be calculated for different conditions using the proposed method, by modifying the criterion-relative membership vectors by altering the criterion-characteristic values.

This study provided quantitative analysis of the effect of meteorological factors on water pricing, using the SWP model for Xi'an City (Shaanxi Province, China). The SWP model presented in this paper offers some new directions in the research on water pricing. The results indicate that the SWP model is practical for fixing prices of urban water resources and could be applied in other, similar cities.

# Acknowledgements

This work was supported by the Major Programs of the Chinese Academy of Sciences under Grant KZZD-EW-04-03; and the National Natural Science Foundation of China under Grant 41271295.

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