Spatio-Temporal Variations of Crop Water Footprint and Its Influencing Factors in Xinjiang, China during 1988–2017

Aihua Long 1,2, Pei Zhang 2,*, Yang Hai 2, Xiaoya Deng 2, Junfeng Li 1, and Jie Wang 1

1 College of Water Conservancy and Architectural Engineering, Shihezi University, Shihezi 832003, China; ahlong@iwhr.com (A.L.); ljfshz@126.com (J.L.); wanjie04085353@163.com (J.W.)
2 State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin, China Institute of Water Resources and Hydropower Research, Beijing 100038, China; haiy_iwhr@163.com (Y.H.);
Lily80876@163.com (X.D.)
* Correspondence: zhangpei-cool@163.com; Tel.: +86-10-6878-5706

Received: 18 September 2020; Accepted: 16 November 2020; Published: 19 November 2020

Abstract: Scientifically determining agricultural water consumption is fundamental to the optimum allocation and regulation of regional water resources. However, traditional statistical methods used for determining agricultural water consumption in China do not reflect the actual use of water resources. This paper determined the variation in the crop water footprint (CWF) to reflect the actual agricultural water consumption in Xinjiang, China, during the past 30 years, and the data from 15 crops were included. In addition, the STIRPAT (stochastic impacts by regression on population, affluence and technology) model was used to determine the factors influencing the CWF. The results showed that the CWF in Xinjiang increased by 256% during the 30-year period. Factors such as population, agricultural added value, and effective irrigated area were correlated with an increase in the CWF. This study also showed that the implementation of national and regional policies significantly accelerated the expansion of agricultural production areas and increased the amount of agricultural water used. The objectives of this paper were to identify the factors influencing the CWF, give a new perspective for further analysis of the relationship between agricultural growth and water resources utilization, and provide a reference for local policy decision-makers in Xinjiang.

Keywords: agricultural added value; agricultural water consumption; irrigation area; political drive; water resources

1. Introduction

Water safety and food security are two essential issues in the world today. China suffers from insufficient per capita water resources, and as the social economy develops and living standards improve, water supplies will be even scarcer in the next 20 years in China [1]. Thus, water shortages will increasingly constrain food security and other severe problems are expected, especially in arid land. Under this condition, virtual water strategies are intended to provide a new way to relieve the pressure on regional water resources and achieve sustainable regional development [2,3]. For example, water resources in water-deficient areas can be saved by importing products containing high levels of water to substitute local products. However, in the arid lands of China, the development and utilization of water resources are not in line with virtual water strategies, and, in fact, are playing an opposite role. Specifically, in some water shortage areas, water flows out with the exportation of agricultural products, in the form of virtual water [4].

Agricultural water accounts for 70–75% of the global water consumption [5,6]. In arid areas such as Xinjiang, the exploitation of water in agricultural production affects the ecosystem [7].
Therefore, scientifically quantifying agricultural water use is the basis for reasonable utilization and allocation of regional water resources. The Chinese government has collected water consumption data from the relevant local departments. However, there are inconsistencies in the data acquired from different departments and these data do not reflect the actual water use. For instance, annual agricultural water consumption in Xinjiang slowly increased from $46.39 \times 10^9$ m$^3$ in 2001 to $49.60 \times 10^9$ m$^3$ in 2010 according to the Xinjiang Water Resources Bulletin. However, the First National Water Census showed that agricultural water consumption in 2010 was $59.18 \times 10^9$ m$^3$, representing a difference of almost $10^{10}$ m$^3$. To determine how agricultural water is utilized and to quantify the pressure placed on water resources from agricultural production activities, this paper used a new method for measuring agricultural water consumption based on the theory of the water footprint. The water footprint theory, proposed in 2003, can reflect the real demand and utilization of water resources in a region or country, and reflect the consequences of human and societal reliance on water sources and the environment [8,9].

The crop water footprint (CWF) is the main factor affecting the water footprint, due to the high coverage area of crops on earth.

The CWF consists of three types: green, blue and gray water footprints. The green water footprint refers to the precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation, i.e., the part of precipitation that evaporates or is transpired through plants. The blue water footprint refers to the volume of surface and groundwater consumed as a result of the production of crops. The gray water footprint indicates the freshwater pollution that can be associated with the production of a product over its full supply chain. Research on the CWF generally focuses on three aspects. The first is examining the water footprint production of typical and staple crops [10–13] or comparing CFWs across different regions and providing new ideas for solving the problem of water shortage and optimizing the management of water resources [9,14–16]. The second is evaluating the pressure on water resources due to agricultural production activities, such as the structure and efficiency of water use based on the CWF, to optimize the structure of agricultural planting [17,18]. The third is preliminarily exploring the effect of meteorological and agricultural input factors on the production of the CWF (i.e., fresh water consumption per unit crop yield) [19–21], to regulate the input of agriculture and to achieve high efficiency of water use. However, previous studies have merely discussed the factors influencing production of the CWF; few have explored the total amount of CWF and its driving forces.

The CWF is based on the water consumption of crops over the growing period, planting structure and crop yield per unit area [22]. Water consumption is mainly determined by the local agro-meteorological conditions (e.g., temperature, wind speed and precipitation), and crop yield per unit area is mainly influenced by agricultural inputs (e.g., fertilizer consumption and power of agricultural machinery) [19]. Factors such as agro-meteorological conditions and agricultural inputs are directly involved in the growth process of crops and regarded as factors directly influencing the CWF [23]. Thus, many scholars focus on the impacts of climate variability and agricultural inputs on the CWF by exploring contributing factors through the Cobb–Douglas production function, path analysis and fuzzy mathematics [19,23]. However, factors such as population (herein, total amount of people, not labor for agriculture) and urbanization level, which are not directly involved in the process of agricultural production but indeed drive variation in the CWF by increasing the demand for crops, have seldom been discussed in previous research.

The objectives of this study were to reveal the variation in the CWF during 1988–2017, to discuss the social and political factors influencing the CWF, and to provide a new perspective for further analysis of the relationship between agricultural growth and water resource development and utilization in Xinjiang. We analyzed the spatio-temporal variation of the CWF during 1988–2017, explored the trend and abrupt changes in the CWF, and determined the influencing factors using the STIRPAT (stochastic impacts by regression on population, affluence and technology) model. Finally, we examined the influence of national and regional policies on the CWF. This paper contributes to both CWF studies and governance of local water utilization: Firstly, we classified influencing factors as either direct
or indirect, and proposed different physical models for the different factors; secondly, we revealed that the variation in irrigated areas influenced by policies was the key driver of the CWF and, thus, reducing the irrigated area might be an important way to reduce water consumption of agricultural production and solve the water usage dilemma in arid areas similar to Xinjiang.

2. Materials and Methods

2.1. Study Area

Xinjiang, located in the hinterland of China (34°09′–49°08′ N, 73°25′–96°24′ E), covers an area of $1.66 \times 10^6$ km$^2$ and accounts for 16.7% of the national land area of China. Xinjiang is surrounded by high mountains, with the Tianshan Mountains dividing it into North, South and East Xinjiang. There are five prefectures in South Xinjiang (Aksu Prefecture, Bayingol Mongolian Autonomous Prefecture, Kizilsu Kirgiz Autonomous Prefecture, Kashgar Prefecture and Hotan Prefecture); seven prefectures and cities in North Xinjiang (Urumqi City, Karamay City, Changji Hui Autonomous Prefecture, Bortala Mongolian Autonomous Prefecture, Tacheng Prefecture, Ili Kazak Autonomous Prefecture and Altay Prefecture); and one prefecture and one city in East Xinjiang (Hami Prefecture and Turpan City). Xinjiang has a typical continental climate with mean annual precipitation of 146.4 mm and potential annual evaporation of 1600–2300 mm [24,25]. Average annual precipitation in North, South and East Xinjiang were 296, 142 and 91 mm during 1956–2016, respectively. Xinjiang has high annual average sunshine (about 2800 h), relatively great differences in daily temperature and accumulated temperature, and good conditions of light, heat and land resources—advantages that benefit agricultural production [25].

In 2017, the Gross Regional Product of Xinjiang was $1088 \times 10^9$ Chinese Yuan, of which the added value of primary industry accounted for 14.25%. The cultivated area of crops was $6.84 \times 10^6$ hm$^2$, of which cotton had the largest area of $2.45 \times 10^6$ hm$^2$, followed by wheat and maize with areas of $1.16 \times 10^6$ and $1.02 \times 10^6$ hm$^2$, respectively. Total water consumption in Xinjiang was $55.23 \times 10^9$ m$^3$, with $51.44 \times 10^9$ m$^3$ for agricultural irrigation [26]. Thus, irrigation was the primary use for water, accounting for 93.14% of total water consumption.

2.2. Data Analyses

The main crops in Xinjiang, including wheat, maize, rice, potato, beans, cotton, oil crops, sugar beet, vegetables, melon, apple, pear, grape, jujube and alfalfa, were studied in this paper. Data related to population, agricultural production (including crop yield, cultivated area, and yield per unit area), agricultural added value and effective irrigated area were obtained from the Statistical Yearbook of Xinjiang [27] and the Production and Construction Corps [28]. Monthly meteorological data during 1988–2017 were acquired from the 88 weather stations in Xinjiang from the website of the China Meteorological Administration [29], including rainfall, sunshine duration, wind speed, relative humidity, and maximum and minimum temperatures. Data of irrigated water usage were acquired from the Water Source Bulletin of Xinjiang [30] and the Water Source Bulletin of China [31].

CropWat 8.0 was used to calculate the reference crop evapotranspiration and effective precipitation. Monthly meteorological data during 1988–2017 are input in the CropWat model. Crop and soil parameters were provided by FAO [32]. Statistical analysis was processed in SPSS 20.0 (SPSS Inc., Armonk, NY, USA).

2.3. Calculation of the CWF

The CWF consists of three types of water footprint: green, blue and gray. The blue type refers to the consumption of surface water and groundwater; the green type refers to the consumption of rainwater insofar as it does not become runoff; and the gray type refers to the volume of freshwater
required to adjust the pollutant load so it is in line with given water quality standards [22,33]. We calculated the CWF based on the method of Hoekstra [22] as follows:

\[ WF_{\text{proc}} = WF_{\text{proc,blue}} + WF_{\text{proc,green}} \] (1)

where \( WF_{\text{proc}} \) is the CWF volume in productive process (m\(^3\)/hm\(^2\)); \( WF_{\text{proc,blue}} \) is the volume of the blue CWF (m\(^3\)/hm\(^2\)); and \( WF_{\text{proc,green}} \) is the volume of the green CWF (m\(^3\)/hm\(^2\)).

\( WF_{\text{proc,green}} \) is calculated as follows:

\[ WF_{\text{proc,green}} = CWU_{\text{green}} / Y, \] (2)

\[ CWU_{\text{green}} = 10 \times \sum_{d=1}^{l_{\text{gp}}} ET_{\text{green}}, \] (3)

\[ ET_{\text{green}} = \min(ET_c, P_{\text{eff}}), \] (4)

where \( CWU_{\text{green}} \) is the volume of the green type of water usage of crops (m\(^3\)/hm\(^2\)); \( Y \) is the yield of crop per unit area (kg/hm\(^2\)); \( ET_{\text{green}} \) is the green type of water requirement of crops, represented by crop evapotranspiration (mm); 10 is the conversion coefficient for precipitation depth to water volume per unit land area (m\(^3\)/hm\(^2\)); \( d \) is the planting date; \( l_{\text{gp}} \) represents the length of the growing period (d); \( ET_c \) is the crop evapotranspiration (mm), calculated with software CropWat 8.0 as recommended by FAO; and \( P_{\text{eff}} \) is the effective precipitation for crops (mm).

\( WF_{\text{proc,blue}} \) is calculated as follows:

\[ WF_{\text{proc,blue}} = CWU_{\text{blue}} / Y, \] (5)

\[ CWU_{\text{blue}} = 10 \times \sum_{d=1}^{l_{\text{gp}}} ET_{\text{blue}}, \] (6)

\[ ET_{\text{blue}} = \max(0, ET_c - P_{\text{eff}}), \] (7)

where \( CWU_{\text{blue}} \) is the volume of the blue type of water usage of crops (m\(^3\)/hm\(^2\)) and \( ET_{\text{blue}} \) is the blue type of water requirement of crops (mm). The other variables are the same as in Equations (2)–(4). Thus, the CWF can be calculated as follows:

\[ CWF = \sum_{i=1}^{n} (WF_{i,\text{proc,blue}} + WF_{i,\text{proc,green}}) \times Y_i, \] (8)

where \( i \) is the crop category and \( Y_i \) is the area of crop \( i \) (hm\(^2\)).

This study did not determine the gray type of water footprint because scholars have not reached a consensus on the calculation methods [34], and the volume of the gray type of water footprint in crop production is very small in Xinjiang [35].

### 2.4. STIRPAT Model

Based on the IPAT (Impact Population Affluence Technology) equations that describe the multiplicative contributions of population (P), affluence (A) and technology (T) to environmental impact (I), York et al. [36] proposed the stochastic regression model, i.e., STIRPAT model to research dynamic couplings (e.g., population, affluence and technology) between human systems and ecosystems.

\[ I = a P^b A^c T^d, \] (9)

where \( I \) is the impact of social activity on the environment (herein, the CWF was used to express the impact of anthropogenic activities on water resources (10\(^9\) m\(^3\))); \( P \), \( A \) and \( T \) are the population,
affluence and technical factors, respectively; a is the model coefficient; and b, c and d are the elasticity coefficients of population, affluence and technology, respectively. The elasticity coefficient b indicates that when the values of A and T were constant, a change in P of 1 unit increased I by a factor of b units correspondingly. A similar argument applies to c and d.

To facilitate parameter estimation, we converted the multivariate nonlinear model in Equation (11) into a linear equation by logarithmization [20]:

$$\ln I = \ln a + b \ln P + c \ln A + d \ln T + e,$$

(10)

where e is the error term. We extended the STIRPAT model by taking the urbanization level, effective irrigated area and other factors into consideration, expressed as Equation (11):

$$\ln I = \ln a + b_1 \ln P_1 + b_2 \ln P_2 + c \ln A + d_1 \ln T_1 + d_2 \ln T_2 + d_3 \ln T_3,$$

(11)

where $P_1$ is the total population of Xinjiang; $P_2$ is the urbanization percentage, expressed as the proportion of urban population to the total population (%); $A$ is the affluence, expressed by the agricultural added value (Chinese Yuan/hm$^2$); $T_1$ is the water use intensity, expressed as the amount of water used for agricultural added value (m$^3$/Chinese Yuan); $T_2$ and $T_3$ are the grain crops yield per unit area (kg/hm$^2$) and effective irrigated area (hm$^2$), respectively. $b_1$, $b_2$, $c$, $d_1$, $d_2$ and $d_3$ are the elasticity coefficients.

2.5. Partial Least-Squares Regression (PLSR) and Path Analysis Methods

In the STIRPAT model, regression is needed to calculate the elasticity coefficients (e.g., of population, urbanization percentage, affluence and water intensity). However, there were strong correlations among these factors, which would lead to serious collinearity among factors, and ordinary least-squares regression could not solve this problem. PLSR developed by the Svante Wold group can effectively solve the problem of multi-correlation among independent variable factors [37–41]. Therefore, to eliminate the effect of multi-collinearity and improve the accuracy and stability of the model, we used the PLSR method in regressing when calculating elasticity coefficients. The theory and methodology of PLSR can be found in Geladi and Kowalski [42] and Wold et al. [40].

One objective of this study was to determine which factors contribute most to increases in the CWF. However, the interrelationship between influencing factors is complicated and some independent factors indirectly affect the CWF through other independent factors. For example, population might affect the CWF via the effect of affluence on the GDP. Thus, path analysis is introduced. Path analysis is a form of multiple regression statistical analysis that is used to evaluate causal models by examining the relationships between a dependent variable and two or more independent variables [43,44]. It is useful in making explicit the rationale of conventional regression calculations. By using this method, one can estimate both the magnitude and significance of causal connections between variables, including direct and indirect influences. The theory and methodology of path analysis can be found in Duccan [45] and Liu et al. [46].

3. Results

3.1. Spatial-Temporal Variation of the CWF in Xinjiang

As the calculation of Equations (1) to (8), we revealed the CWF in Xinjiang significantly increased from $13.02 \times 10^9$ m$^3$ in 1988 to $51.03 \times 10^9$ m$^3$ in 2017 (Table 1), an increase of 256% ($Z = 6.50, p < 0.001$).
Table 1. Crop water footprint ($10^9$ m$^3$) in South, North and East Xinjiang during 1988–2017.

| Year | South Xinjiang | North Xinjiang | East Xinjiang | Total |
|------|----------------|----------------|---------------|-------|
| 1988 | 7.39           | 4.35           | 1.28          | 13.02 |
| 1990 | 9.52           | 9.83           | 1.52          | 20.87 |
| 1992 | 9.33           | 7.31           | 1.24          | 17.88 |
| 1994 | 9.88           | 7.62           | 1.12          | 18.62 |
| 1996 | 9.86           | 8.84           | 1.21          | 19.91 |
| 1998 | 9.93           | 8.51           | 1.18          | 19.62 |
| 2000 | 11.91          | 8.92           | 1.28          | 22.11 |
| 2002 | 12.38          | 9.1            | 1.51          | 22.99 |
| 2004 | 12.77          | 8.97           | 1.71          | 23.45 |
| 2006 | 13.99          | 9.46           | 1.64          | 25.09 |
| 2008 | 18.41          | 12.83          | 1.9           | 33.14 |
| 2010 | 19.27          | 12.48          | 1.91          | 33.66 |
| 2012 | 21.3           | 15.51          | 2.22          | 39.03 |
| 2014 | 27.49          | 18.24          | 2.58          | 48.31 |
| 2016 | 31.15          | 17.08          | 2.54          | 50.78 |
| 2017 | 29.35          | 18.94          | 2.74          | 51.03 |

The CWF was larger in South than in North Xinjiang and much larger than in East Xinjiang (Table 1). The CWF in all parts of Xinjiang increased during the study period, but increase magnitudes varied. Specifically, the CWF increased by $21.96 \times 10^9$, $14.59 \times 10^9$ and $1.46 \times 10^9$ m$^3$, with increase rates of 397%, 435% and 214% in South, North and East Xinjiang during 1988–2017, respectively.

The percentage of the CWF used by each crop varied, i.e., the proportion of grain crops (rice, wheat and maize) gradually decreased and that of industrial crops increased, notably so for cotton; the proportion of cotton increased from 16% to 47% (Figure 1). The increase rate in industrial crops was larger than that of grain crops. Specifically, the CWF of cotton, soybean, jujube and pear increased by more than 1000% during the study period; the increase in maize, sugar beet, vegetables, melons, potato, alfalfa, grape and apple ranged from 200% to 400%, and those of rice, wheat and oil crops did not significantly change.

![Figure 1](image_url). Percentage of the crop water footprint used by different crops in Xinjiang during 1988–2017.
The WF_{blue} originating from irrigated water increased by 119%, from $19.43 \times 10^9$ m$^3$ in 2001 to $42.55 \times 10^9$ m$^3$ in 2017 (Table 2). Correspondingly, irrigated water increased from $37.75 \times 10^9$ to $55.59 \times 10^9$ m$^3$ during 2001–2012, but decreased afterward, and the conversion coefficient increased from 51% to 83%. The increase in the blue CWF, accompanied by a decrease in irrigated water since 2012, indicates improvements in irrigation and management technology during this time, which is reflected by the increase of the conversion coefficient.

Table 2. Blue crop water footprint and irrigated water in Xinjiang during 2001–2017.

| Year | Blue CWF ($10^9$ m$^3$) | Irrigated Water ($10^9$ m$^3$) | Conversion Coefficient (%) |
|------|-------------------------|-------------------------------|---------------------------|
| 2001 | 19.43                   | 37.75                         | 51                        |
| 2002 | 18.36                   | 35.20                         | 52                        |
| 2003 | 16.49                   | 35.46                         | 46                        |
| 2004 | 19.59                   | 35.65                         | 55                        |
| 2005 | 18.56                   | 46.51                         | 40                        |
| 2006 | 21.49                   | 46.73                         | 46                        |
| 2007 | 24.01                   | 47.35                         | 51                        |
| 2008 | 29.94                   | 48.26                         | 62                        |
| 2009 | 29.47                   | 48.63                         | 61                        |
| 2010 | 26.26                   | 48.83                         | 54                        |
| 2011 | 32.60                   | 48.62                         | 67                        |
| 2012 | 32.37                   | 55.59                         | 58                        |
| 2013 | 32.32                   | 55.05                         | 59                        |
| 2014 | 41.34                   | 54.39                         | 76                        |
| 2015 | 37.54                   | 54.06                         | 69                        |
| 2016 | 39.67                   | 52.77                         | 75                        |
| 2017 | 42.55                   | 51.44                         | 83                        |

3.2. Factors Influencing the CWF

Continuous increases in population and living standards have put greater pressure on resources and the environment. The population, economy and technology will, to some extent, affect the consumption of water resources. Therefore, we used the STIRPAT model to quantitatively study the influences of population, urbanization, agricultural added value, water intensity, grain crops yield per unit area, and effective irrigated area on the CWF. Variations among these six factors in Xinjiang during the study period are shown in Figure 2, and the result of Pearson’s analysis is shown in Table 3.

All these factors showed increasing trends during the past 30 years, except for water intensity, which decreased (Figure 2). In Table 3, except for urbanization percentage ($P_2$), all studied factors were significantly correlated with the CWF, indicating that anthropogenic activities had a great impact on water resources. The elasticity coefficients of these factors were calculated using the PLS method (Table 4).

The result of elasticity coefficient analysis showed that urbanization percentage, irrigated water intensity, and grain crops yield per unit area were negatively correlated with the CWF (Table 4). Specifically, even though enhancement of urbanization level had an inhibitory influence on the CWF, the correlation coefficient of urbanization percentage was 0.21 ($p > 0.05$; Table 4), indicating that the CWF was not sensitive to regional urbanization. The increase in irrigated water intensity and grain crops yield per unit area were due to the improvement and popularization of efficient water-saving technologies, both of which contributed to the reduction in agricultural water use. In contrast, there were positive correlations of the CWF with population, agricultural added value, and effective irrigated area.
Figure 2. Variations in population, urbanization percentage, agricultural added value, water intensity, grain crops yield per unit area, and effective irrigated area in Xinjiang during 1988–2017.

Table 3. Pearson’s analysis among factors influencing the CWF (crop water footprint).

| Factor  | LnI   | LnP₁ | LnP₂ | LnA  | LnT₁ | LnT₂ | LnT₃ |
|---------|-------|------|------|------|------|------|------|
| LnI     | 1.00  | 0.89 ** | 0.26 | 0.94 ** | −0.72 ** | 0.81 ** | 0.97 ** |
| LnP₁    | 1.00  |       | 0.41 * | 0.90 ** | −0.77 ** | 0.95 ** | 0.87 ** |
| LnP₂    | 1.00  |       |       | 0.26 | −0.22 | 0.49 ** | 0.22 |
| LnA     | 1.00  |       |       |       | −0.91 ** | 0.90 ** | 0.96 ** |
| LnT₁    | 1.00  |       |       |       |       | −0.85 ** | −0.80 ** |
| LnT₂    | 1.00  |       |       |       |       |       | 0.84 ** |
| LnT₃    | 1.00  |       |       |       |       |       |       |

Note: I, CWF; P₁, population; P₂, urbanization percentage; A, agricultural added value; T₁, water intensity; T₂ and T₃ are the grain crops yield per unit area and effective irrigated area, respectively. * and ** indicate significance at $p < 0.05$ and $p < 0.01$, respectively.

Table 4. Elasticity coefficient analysis among factors influencing the CWF.

|            | LnP₁ | LnP₂ | LnA | LnT₁ | LnT₂ | LnT₃ |
|------------|------|------|-----|------|------|------|
| LnP₁       | 0.21 | −0.06 | 0.48 | −0.17 | −0.02 | 0.53 |

In addition, the effects and contribution rate of these factors on the CWF were calculated using path analysis (Table 5).
Table 5. Effects of factors influencing the CWF.

| Factor          | \( p_1 \) | \( p_2 \) | \( A \) | \( T_1 \) | \( T_2 \) | \( T_3 \) |
|-----------------|----------|----------|--------|----------|----------|----------|
| Direct effect   | 0.21     | -0.06    | 0.48   | -0.17    | -0.02    | 0.53     |
| Indirect effect | 0.19     | -0.04    | 1.01   | -0.45    | -0.06    | 2.05     |
| Total effect    | 0.40     | -0.10    | 1.49   | -0.62    | -0.08    | 2.58     |

Path analysis showed that all the effects (direct, indirect and total effects) of effective irrigated area were the highest among the factors, with values of 0.53, 2.05 and 2.53, respectively. Thus, we conclude that enlargement of irrigated areas was the main factor boosting the increase in the CWF. To validate this conclusion, we illustrate the variations in irrigated area and the CWF over the study period (Figure 3).

Variations in the CWF were highly synchronous with variations in irrigated area; i.e., before 2005, the irrigated area and CWF increased slowly, but thereafter, both increased sharply (Figure 3). As the area designated for irrigation is determined by governmental policy [23,47–49], we discuss the political influence on the CWF in the following section.

3.3. Politically Driven Increase in the CWF

The increase in the CWF resulted from the expansion of cultivated areas that was driven by economic development, including investment in agricultural resources, poverty alleviation and the national aid policy for Xinjiang. In the following section, we divide the increase in the CWF into four stages according to the implementation of key policies in Xinjiang and explore politically driven effects on the increase in the CWF.

The first stage was pre-1992, before the year of the 14th National Congress of the Communist Party of China (CPC). Although the great policy of “China’s Reform and Opening-up” proposed by the CPC has been gradually implemented and the priority of national works was transferred to economic construction, the main task in Xinjiang was to maintain stability and primarily develop industry instead of economic construction before 1992 [50,51]. The second stage was the period 1992–2000, when the Government of Xinjiang implemented the “Black and White” policy by attracting investment by large enterprises and groups in agriculture and energy industries to convert resources (such as land, light and heat resources in agriculture, coal and gas production) into economic advantages [52]. “Black” (herein, petroleum petrochemical energy such as the coal sector) and “White” (cotton and cotton textile
sectors) were the pillars of the regional economy in Xinjiang and, for example, the output value of cotton has accounted for 50% of the agricultural output value [53]. However, determining the actual effect of this policy is complicated, as some enterprises and individuals reclaimed farmland without planning under the connivance of local government.

The third stage was from 2001 to 2010, when large-scale development of Western China was proposed and primarily implemented. Xinjiang was one of the main provinces on which the strategy was focused, due to the abundant natural resources and low personal incomes [54]. After the 16th National Congress of the CPC in 2002, the Party Central Committee and the State Council agreed that development of Xinjiang needed input from the whole country, and put forward a strategy of “stabilizing Xinjiang, enriching the people and solidifying the frontier”. A series of anti-poverty programs and essential deployments to Xinjiang were carried out, mainly focused on farmland and water conservancy, construction and improvement of rural roads, and availability and safety of drinking water for people and livestock [55]. More importantly, agricultural water conservancy and farmland reclamation accounted for 50–60% of the capital investment, and the funds for water conservancy construction of farmland accounted for more than 35% during 2001–2004 [56]. Investment in water conservancy and farmland reclamation directly facilitated the expansion of agricultural planting areas. At the same time, local governors spent the poverty alleviation fund on the development and construction of high-quality cotton, special forestry, artificial forage and ecological forest bases, land remediation and development, and comprehensive agricultural development, all of which resulted in a rapid and continuous increase of the irrigated area.

The fourth stage was after 2010, when the partner aid to Xinjiang came into force. Due to its weak industrial foundation, low technology level, and distance from the mainland market, it is hard for Xinjiang to develop industry, and partner aid governments are unlikely to be interested in such projects. In contrast, agriculture in Xinjiang requires less investment and provides quick paybacks, thus, farmland reclamation, construction of high-efficiency water-saving areas, and development of eco-agricultural demonstration gardens became the most common methods for many partner aid provinces. For example, the government of Beijing City spent $15 \times 10^6$ Chinese Yuan on reclaiming 180 hm$^2$ of farmland in Cele County, in the year 2011 alone [55].

This paper split the study period into four stages to explore the response of the CWF to the implementation of the above-mentioned policies (Figure 4). The annual rate of increase in the CWF in the first stage was $0.47 \times 10^9$ m$^3$/a. After the “Black and White” policy was implemented in 1992, this increased to $0.56 \times 10^9$ m$^3$/a. Due to large-scale development in Western China and poverty alleviation in the third stage, the annual rate of increase was $1.37 \times 10^9$ m$^3$/a, an increase of 245% compared to the second stage. Following implementation of the partner assistance policy in 2010, the rate increased to $2.57 \times 10^9$ m$^3$/a. Astonishingly, the annual rate increase in the CWF in the most recent 7 years (2011–2017) was even higher than that in the previous 10 years (2001–2010).

Previous research showed that the annual rate of increase of arable area rose rapidly from $6.88 \times 10^3$ hm$^2$/a in 1990–2000 to $38.77 \times 10^3$ hm$^2$/a in 2010–2017 [48,49]. Thus, the partner aid policy increased and astonishingly accelerated expansion of the irrigated farmland in Xinjiang. Increases in irrigated area and the CWF were closely related to the construction of agricultural conveyance projects [23]: (1) comprehensive management of the Tarim River made it easier for agricultural irrigation in South Xinjiang; and (2) water transfer projects from the Irtysh River to Urumqi and Karamay, and Qiafuqihai Dam and Jilintai First Stage Hydropower Station in the Illy River enhanced the convenience of agricultural irrigation and drove a sharp expansion of planting areas in North Xinjiang.
3.4. Methods to Relieve the Water Use Dilemma

Agricultural water consumption in Xinjiang accounted for 95% of national water usage, and with the increase in irrigated areas, water consumption will increase correspondingly. In order to relieve the water use dilemma of agricultural water usage, methods such as the application of water-saving technology and withdrawal of farmland have been proposed.

Xinjiang is a region in which water-saving technology has been developed, and $3.47 \times 10^6$ ha or more than half of the irrigated area utilizes water-saving equipment. The water resources conserved using water-saving technology are mainly used to enlarge the scale of irrigation; the enlargement of irrigated areas raises the need for water resources, which leads to the Jevons paradox in water-saving, i.e., the more water-saving technology used, the greater the water requirements \[57, 58\]. An increase in efficiency of water usage driven by technological progress does not reduce energy consumption necessarily, but causes more consumption and accelerates the depletion of water resources. In addition, the arid climate and inland basin conditions lead to severe soil salinity across most of the area \[59\]. The development and popularization of water-saving technology will cause accumulation of salinity under the soil surface (2–3 m), and the longer the process proceeds, the more salt will accumulate, which will accelerate degradation of soil \[60\]. Thus, as improvements in salt transfer processes and a solution to salinity accumulation have not been developed, large-scale implementation of water-saving technology is not suitable for Xinjiang.

Withdrawal of planting areas is currently a popular measure to reverse the negative influence of water over-exploitation on the eco-environment, including administrative and non-administrative methods. Administrative methods mainly focus on the compulsory withdrawal of farmland and agricultural water utilization, such as prohibition of farmland beyond planning and shutdown of groundwater wells for irrigation. Non-administrative methods include raising the price of irrigated water and agricultural input elements such as pesticides and fertilizers \[61\], to reduce the area of water-intensive crops \[62\]. These methods indeed have a positive effect on the regulating of planting area and reducing the agricultural water utilization, and the agricultural water utilization was reduced by 13% from 2012 to 2018 \[30\]. However, some failure and losses emerge concurrently. Irrigated water, fertilizers and pesticides are fundamental inputs for agricultural production to guarantee high crop yields, and if their prices rise, the benefits for farmers will decrease correspondingly; if the benefits for farmers decrease, the farmers have little aspiration in agricultural production, and thus, some of them leave Xinjiang, which negatively
affects the unity of local groups and political stability. Therefore, any method and policy should be foreseen in the functioning, failures and losses before they come into force [63].

Xinjiang is at a disadvantage because of its low technology level, weak industrial development foundation, and distance from mainland markets [64]. However, large areas of land, excellent sunshine conditions and high differences in temperature make Xinjiang a good agricultural base [25]. Thus, water is the only factor restricting the development of agricultural production, and if water were sufficient, Xinjiang could be the largest food base in China.

Is Xinjiang really short of water resources? Many researchers have claimed that the total water resources in Xinjiang are almost $90 \times 10^9$ m$^3$, and the water resources per capita is $3520$ m$^3$, which is 1.75 times the national level [26] and, thus, Xinjiang does not lack water. However, most water resources are transferred out of Xinjiang in the form of virtual water, with the trade of agricultural products to other places in China, and even abroad. For example, Ma et al. revealed that in the year of 2012, the total water consumption for production in Tarim River basin in South Xinjiang was $35.9 \times 10^9$ m$^3$, but the net virtual water transferred out of the territory was $19.9 \times 10^9$ m$^3$, accounting for 55% of regional water consumption [65]. This indicated that more than half of the fresh water in Xinjiang was not consumed by the people of Xinjiang. Thus, we consider that physical water should be transferred into Xinjiang to compensate for the virtual water transferred out.

4. Conclusions and Perspectives

Our evaluation of the temporal–spatial variation and factors influencing the CWF in Xinjiang over the last 30 years showed some generalizable and specific results. Firstly, direct and indirect factors influencing the CWF were separated according to crop production, and we recommended STIRPAT models for the analysis of indirect factors because of its physical mechanism. Secondly, we further revealed that irrigated area was the key factor influencing the CWF, based on the results of previous studies showing that human activity has a greater contribution to the CWF than natural factors such as climate. Considering this, it seems that withdrawal of irrigated areas might be an effective way to solve the water use dilemma of Xinjiang and other similar areas. However, upon considering political elements, low inputs of the labor force, and the good conditions for agricultural production, we believe that the only one limitation for agricultural production is lack of water. In addition, previous research indicates that more than half of virtual water is transported out of Xinjiang through agricultural product trade, we recommend that physical water should be transferred into Xinjiang in compensation. These results and recommendations could be applied to other similar areas to enrich water footprint studies and guide the local governance of water usage.

Xinjiang suffers from a scarcity of fresh water, even though it plays essential roles in agricultural production (e.g., cotton) in the national economy. Fresh water resources in Xinjiang are exported along with the trade of agricultural products, resulting in “west-to-east water transfer in the form of virtual water”. Therefore, from the perspective of ecological compensation, how much virtual water is transported outward through agricultural products? To which provinces and cities is water mainly transported? These questions will be further discussed in the next step of our research.

Author Contributions: A.L. and P.Z. wrote the main manuscript text and prepared figures. X.D. advised the study design and data analyses. Y.H. collected the data and calculated the crop water footprint. J.L. revised the paper. J.W. carried out the STIRPAT analysis. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Key Technology R&D Program of China (2017YFC0404301, 2016YFA0601602) and the National Natural Science Foundation of China (51479209, 51609260, U1803244).

Conflicts of Interest: We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work; there is no professional or other personal interest of any nature or kind in any product, service or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled “Spatio-temporal variations of crop water footprint and its influencing factors in Xinjiang, China during 1988–2017”.
References

1. Jiang, Y. China’s water scarcity. *J. Environ. Manag.* **2009**, *90*, 3185–3196. [CrossRef] [PubMed]
2. Allan, J.A. Virtual water—The water, food, and trade nexus. *Useful Concept or Misleading Metaphor? Water Int.* **2003**, *2*, 106–113. [CrossRef]
3. Cheng, G.D. Virtual water—A strategic instrument to achieve water security. *Bull. Chin. Acad. Sci.* **2003**, *18*, 260–265. (In Chinese)
4. Jia, S.F.; Long, Q.B.; Liu, W.H. The fallacious strategy of virtual water trade. *Int. J. Water Resour. Dev.* **2016**, *1–8*. [CrossRef]
5. Duarte, R.; Yang, H. Input–output and water: Introduction to the special issue. *Econ. Syst. Res.* **2011**, *23*, 341–351. [CrossRef]
6. Creating a Sustainable Food Future: Interim Findings. Available online: https://www.wri.org/publication/creating-sustainable-food-future-interim-findings (accessed on 18 September 2020).
7. Piao, S.L.; Fang, J.Y.; Zhou, L.M.; Ciais, P.; Zhu, B. Variations in satellite-derived phenology in China’s temperate vegetation. *Glob. Chang. Biol.* **2003**, *12*, 672–685. [CrossRef]
8. Chapagain, A.K.; Hoekstra, A.Y. Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade. In *Value of Water Research Report Series*; Hoekstra, A.Y., Hung, P.Q., Eds.; UNESCO-IHE: Delft, The Netherlands, 2002; Volume 11, pp. 13–17.
9. Long, A.H.; Xu, Z.M.; Zhang, Z.Q. Estimate and analysis of water footprint in northwest China, 2000. *J. Glaciol. Geocryol.* **2003**, *25*, 692–700. (In Chinese)
10. Chapagain, A.K.; Hoekstra, A.Y.; Savenije, H.G. Water saving through international trade of agricultural products. *Hydrol. Earth Syst. Sci.* **2006**, *10*, 455–468. [CrossRef]
11. Su, M.H.; Huang, C.H.; Li, W.Y.; Tso, C.T.; Lur, H.S. Water footprint analysis of bioethanol energy crops in Taiwan. *J. Clean. Prod.* **2014**, *88*, 132–138. [CrossRef]
12. Suebkam, R.; Trelogan, V.; Konyai, S. The application of deficit water and fertilizer upon yield and water footprint in baby corn. *Int. J. Environ. Rural Dev.* **2015**, *6*, 159–164.
13. Zotou, I.; Tsihrintzis, V.A. The water footprint of crops in the area of Mesogeia, Attiki, Greece. *Environ. Proc.* **2017**, *4*, 1–17. [CrossRef]
14. Aldaya, M.M.; Munoz, G.; Hoekstra, A.Y. Water Footprint of Cotton, Wheat and Rice Production in Central Asia. In *Value of Water Research Report Series*; Hoekstra, A.Y., Hung, P.Q., Eds.; UNESCO-IHE: Delft, The Netherlands, 2010; Volume 41, pp. 13–17.
15. Romaguera, M.; Hoekstra, A.Y.; Su, Z.B.; Krol, M.S. Potential of using remote sensing techniques for global assessment of water footprint of crops. *Remote Sens.* **2010**, *2*, 1177–1196. [CrossRef]
16. Tuninetti, M.; Tamea, S.; D’Odorico, P.; Ridolfi, L. Global sensitivity of high resolution estimates of crop water footprint. *Water Resour. Res.* **2016**, *51*, 8257–8272. [CrossRef]
17. Sun, S.K.; Wu, P.T.; Wang, Y.B.; Zhao, X.N.; Zhang, X.H. The temporal and spatial variability of water footprint of grain: A case study of an irrigation district in China from 1960 to 2008. *J. Food Agric. Environ.* **2012**, *10*, 1246–1251.
18. Xu, Y.J.; Huang, K.; Yu, Y.J.; Wang, X.M. Changes in water footprint of crop production in Beijing from 1978 to 2012: A logarithmic mean Divisia index decomposition analysis. *J. Clean. Prod.* **2015**, *87*, 180–187. [CrossRef]
19. Sun, S.K.; Wu, P.T.; Wang, Y.B.; Zhao, X.N.; Liu, J.; Zhang, X.H. The impacts of inter-annual climate variability and agricultural inputs on water footprint of crop production in an irrigation district of China. *Sci. Total Environ.* **2013**, *444*, 498–507. [CrossRef]
20. Jin, C.; Huang, K.; Yu, Y.J.; Zhang, Y. Analysis of influencing factors of water footprint based on the STIRPAT Model: Evidence from the Beijing agricultural sector. *Water* **2016**, *8*, 513. [CrossRef]
21. Harris, F.; Green, R.F.; Joy, E.J.M.; Kayatz, B.; Haines, A.; Dangour, A.D. The water use of Indian diets and socio-demographic factors related to dietary blue water footprint. *Sci. Total Environ.* **2017**, *587–588*, 128–136. [CrossRef]
22. Hoekstra, A.Y.; Chapagain, A.; Aldaya, A.; Mekonnen, M.M. *The Water Footprint Assessment Manual: Setting the Global Standard*; Earthscan: London, UK, 2011; pp. 25–39.
23. Zhang, P.; Deng, X.Y.; Long, A.H.; Hai, Y.; Li, Y.; Wang, H.; Xu, H.L. Impact of social factors in agricultural production on the crop water footprint in Xinjiang, China. *Water* **2018**, *10*, 1145. [CrossRef]
24. Li, S.; Shi, Y.W.; Zhang, Q.; Liao, X.Y.; Zhu, L.; Lou, K. Phylogenetic diversity of endolithic bacteria in Bole granite rock in Xinjiang. *Acta Ecol. Sin.* 2013, 33, 178–184. (In Chinese) [CrossRef]

25. Zhang, Q.; Sun, P.; Li, J.F.; Singh, V.P.; Liu, J.Y. Spatiotemporal properties of droughts and related impacts on agriculture in Xinjiang, China. *Int. J. Climatol.* 2015, 35, 1254–1266. [CrossRef]

26. China’s Water Resources Bulletin of 2017. Available online: http://www.mwr.gov.cn/sj/tggh/szygb/201811/ P020190829405873356088.pdf (accessed on 16 September 2020). (In Chinese)

27. Statistical Yearbook of Xinjiang. Available online: http://tongji.cnki.net/kns55/Navi/HomePage.aspx?id=N2019101050&name=XYJT&floor=1 (accessed on 16 September 2020). (In Chinese)

28. Statistical Yearbook of Production and Construction Corps. Available online: http://tongji.cnki.net/kns55/Navi/HomePage.aspx?id=N2018110011&name=YPTNY&floor=1 (accessed on 16 September 2020). (In Chinese)

29. China Meteorological Administration. Available online: http://data.cma.cn (accessed on 16 September 2020). (In Chinese).

30. Water Source Bulletin of Xinjiang. Available online: http://www.xjslt.gov.cn/zwgk/slgb/index.html (accessed on 16 September 2020). (In Chinese)

31. Water Source Bulletin of China. Available online: http://www.mwr.gov.cn/sj/tggh/szygb/ (accessed on 16 September 2020). (In Chinese)

32. CropWat. Available online: http://www.fao.org/land-water/databases-and-software/cropwat/en/ (accessed on 16 September 2020).

33. Cao, X.C.; Wu, P.T.; Wang, Y.B.; Zhao, X.N. Water footprint of grain product in irrigated farmland of China. *Water Resour. Manag.* 2014, 28, 2213–2227. [CrossRef]

34. Lovarelli, D.; Bacenetti, J.; Fiala, M. Water footprint of crop productions: A review. *Sci. Total Environ.* 2016, 548–549, 236–251. [CrossRef] [PubMed]

35. Xuan, J.W.; Zheng, J.H.; Liu, Z.H. Calculation and analysis on water footprint of main crops in Xinjiang. *Agric. Res. Arid Area.* 2014, 32, 195–200. (In Chinese)

36. York, R.; Rosa, E.A.; Dietz, T. STIRPAT, IPAT and ImPACT: Analytic tools for unpacking the driving forces of environmental impacts. *Ecol. Econ.* 2003, 46, 351–365. [CrossRef]

37. Lindberg, W.; Persson, J.A.; Wold, S. Partial Least-Squares Method for Spectrofluorimetric Analysis of Mixtures of Humic Acid and Ligninsulfonate. *Anal. Chem. 1983*, 55, 643–648. [CrossRef]

38. Sjostrom, M.; Wold, S.; Lindberg, W.; Persson, J.; Martens, H. Multivariate Calibration Problem in Analytical Chemistry Solved by Partial Least Squares Models in Latent Variables. *Anal. Chim. Acta* 1983, 150, 61–70. [CrossRef]

39. Wold, S.; Albano, C.; Dunn, W.J.; Edlund, U.; Sjöström, M. *Multivariate Data Analysis in Chemistry*; Springer: Berlin, Germany, 1984; pp. 17–95.

40. Wold, S.; Sjostrom, M.; Eriksson, L. PLS-regression: A basic tool of chemometrics. *Chemometr. Intel. Lab.* 2001, 58, 109–130. [CrossRef]

41. Hoskuldsson, A. PLS regression methods. *J. Chemometr.* 1988, 2, 211–228. [CrossRef]

42. Geladi, P.; Kowalski, B.R. Partial least-squares regression: A tutorial. *Anal. Chim. Acta* 1986, 185, 1–17. [CrossRef]

43. Bhantti, G.M. Significance of path coefficient analysis in association. *Euphytica* 1973, 22, 338–343. [CrossRef]

44. Rao, D.C.; Morton, N.E. Path analysis of family resemblance in the presence of gene-environment interaction. *Am. J. Hum. Genet.* 1974, 26, 767–772. [PubMed]

45. Ducan, O.D. Path analysis: Sociological examples. *Am. J. Sociol.* 1996, 72, 1–16. [CrossRef]

46. Liu, G.S.; Xu, D.M.; Xu, Z.J.; Wang, H.Y.; Liu, W.P. Relationship between hydrolase activity in soils and soil properties in Zhejiang province. *Acta Pedol. Sin.* 2003, 40, 756–762. (In Chinese)

47. Cai, W.C.; Yang, D.G. Variation of cultivated land and its driving forces in Xinjiang. *J. Arid Land Resour. Environ.* 2006, 20, 144–149. (In Chinese)

48. Wang, D.; Wu, S.X.; Zhang, S.Y. Expansion of both cultivated and construction land in Xinjiang since the late 1980. *Arid Land Geogr.* 2017, 40, 188–196. (In Chinese)

49. He, K.; Wu, S.X.; Yang, Y.; Wang, D.; Zhang, S.Y.; Yin, N. Dynamic changes of land use and oasis in Xinjiang in the last 40 years. *Arid Land Geogr.* 2018, 41, 1333–1340. (In Chinese)
50. Tao, Y.H.; Miao, H.P.; Wang, H.M. Judgment and analysis of the development stage of agricultural modernization in Xinjiang. In Proceedings of the 2009 Council Working Conference and Academic Seminar of China Agricultural Technology and Economic Research Association, Shenyang, Liaoning Province, China, September 2009. (In Chinese).
51. Huang, L.Y.; Gao, Z.G.; Fu, J. The decomposition analysis of economy gravity center in the view of industry gravity center of Xinjiang in recent 60 years. *J. Xinjiang Univ. Financ. Econ.* 2011, 49, 11–16. (In Chinese)
52. Yang, S.M. Reflections on the development strategy of “Black and White” in Xinjiang. *Decis. Advis. Newsl.* 1998, 9, 13–18. (In Chinese)
53. Cotton Production Value Accounts for Almost Half of Xinjiang’s Agriculture. Available online: http://futures.hexun.com/2015-01-20/172569995.html (accessed on 15 September 2019). (In Chinese).
54. Pu, C.L.; Quan, L. Reflections on the Development of the West and the Anti-Poverty Problem in Xinjiang. *J. Xinjiang Univ. Financ. Econ.* 2000, 4, 5–6. (In Chinese)
55. Zhang, P. Research on the Coupling System of Society, Eco-Environment and Water in Tarim River Basin. Ph.D. Thesis, China Institute of Water Resources and Hydropower Research, Beijing, China, 28 May 2019. (In Chinese).
56. Liu, W.Z. Study on Development Model and Strategy of Rural Poverty Reduction at New Stage in Xinjiang. Ph.D. Thesis, Xinjiang Agricultural University, Urumqi, China, 18 May 2010. (In Chinese).
57. Jevons, W.S. *The Coal Question*; Nabu Press: New York, NY, USA, 2012; pp. 1–418.
58. Wang, Y.Y.; Long, A.H.; Xiang, L.Y.; Deng, X.Y.; Zhang, P.; Hai, Y.; Wang, J.; Li, Y. The verification of Jevons’ paradox of agricultural Water conservation in Tianshan District of China based on Water footprint. *Agric. Water Manag.* 2020, 239, 106163. [CrossRef]
59. Liu, L. Constitute and Distribution character of salinity in soil in Xinjiang. *Arid Environ. Monit.* 2009, 23, 227–229. (In Chinese)
60. Zhang, W.; Lv, X.; Li, L.H.; Liu, J.G.; Sun, Z.J.; Zhang, X.W.; Yang, Z.P. Salt transfer law for cotton field with drip irrigation under the plastic mulch in Xinjiang Region. *Trans. CSAE* 2008, 24, 15–19. (In Chinese)
61. Feng, K.S.; Hubacek, K.; Pfister, S.; Yu, Y.; Sun, L.X. Virtual scarce water in China. *Environ. Sci. Technol.* 2014, 48, 7704–7713. [CrossRef] [PubMed]
62. Happe, K.; Hutchings, N.J.; Dalgaard, T.; Kellerman, K. Modelling the interactions between regional farming structure, nitrogen losses and environmental regulation. *Agric. Syst.* 2011, 104, 281–291. [CrossRef]
63. Pietrucha-Urbanik, K.; Rak, J.R. Consumers’ Perceptions of the Supply of Tap Water in Crisis Situations. *Energies* 2020, 13, 3617. [CrossRef]
64. Yuan, G.L.; Zhang, Y. Rely on industrial parks to push forward the development of processing trade in Xinjiang. *J. Shihezi Univ.* 2012, 26, 23–27. (In Chinese)
65. Ma, Z.; Su, S.J.; Long, A.H.; Zhang, X.X. Water Cycle Analysis of Social and Economic System in Tarim River Basin. *Adv. Earth Sci.* 2018, 33, 833–841. (In Chinese)

**Publisher’s Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).