

## Assessment for the virtual water of agricultural crops from 2000 to 2021 in Taiyuan City

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**Abstract:** Water resources are dramatically important in maintaining the balance of ecosystem services and promoting the sustainable development of the country. Shanxi province which is located in the area of the Yellow River basin suffers from serious issues of water quantity and quality. In general, urbanization has led to increasing human demand for water resources and also increasing agricultural crops to satisfy the requirements of urban population. However, there are no detail reports on the assessment of virtual water for agricultural crops in the areas with severe water shortages, which could better understand the development of water footprint. In our study, based on the water footprint theory, the spatial and temporal changes of virtual green water and blue water of agricultural crops in Taiyuan City were calculated from 2000 to 2021. The results showed that Taiyuan City crop yield per unit area level is low, and the proportion of sown area and total production is gradually decreasing. For both sown area and total production, maize performed best overall. From the 10 districts and counties in Taiyuan City, Qingxu County crop sowing area and total production is the largest, Yingze District crop sowing area and total production is the smallest; from the county unit, Taiyuan City, the east of maize production advantage is higher, the western potato production advantage is higher. The overall share of grain yield of Taiyuan city also has an obvious decreasing trend, from 3.45% to 1.65%. In general, the crop yield in the north and south regions was significantly higher than that in the central region. Both integrated crop production water and virtual blue water in Taiyuan showed fluctuating decreasing trends from 2005 to 2021, while virtual green water showed varying trends over time. The trends of virtual blue water and virtual green water for the crop are overall more consistent, but there are opposite variations in some years. For example, in 2014-2015 and 2018-2019, the virtual blue water volume is increasing while the virtual green water volume is decreasing, and in 2015-2016 and 2019-2020 it is the opposite, so that two completely opposite peaks are formed. The integrated crop production water footprint shows a fluctuating decreasing trend. It reached a maximum value of 11183.29 m<sup>3</sup>/kg in 2009 and decreased to a minimum value of 6009.84 m<sup>3</sup>/kg in 2015. The virtual blue water in all districts and counties of Taiyuan showed a fluctuating downward trend over time. Among them, there are more obvious peaks in individual years. For example, in 2006, the virtual blue water volume in Xinghualing District was 98,439.11 m<sup>3</sup>/kg, and then dropped sharply to 13,605.26 m<sup>3</sup>/kg. There was a significant upward trend in 2009 in Wanbailin district and reached a peak of 58,584.19 m<sup>3</sup>/kg in 2010. In 2017, there was a significant rise in the virtual blue water volume in several regions. Among them, four regions, namely Qingxu County, Jiancaoping District, Xinghualing District and Yangqu County, had more obvious waves. The virtual blue water in Xiaodian District was always stable within 1100 m<sup>3</sup>/kg. The trend of virtual green water over time varies among districts and counties in Taiyuan City. Some regions have more obvious peaks in individual years. In 2006,

the virtual green volume was 67,839.14 m<sup>3</sup>/kg in Xinghualing district, and then dropped sharply to 9685.80 m<sup>3</sup>/kg, and there was a significant increase in green volume in other regions in 2016. In 2009, there was a clear upward trend and reached a peak of 20938.25 m<sup>3</sup>/kg in Wanbailin district, and the amount of green water decreased year by year from 2010 to 2015 and finally fell to 1696.34 m<sup>3</sup>/kg. Coinciding with the blue water data: in 2017, several regions also had significantly higher virtual green volume. Among them, four regions, namely Qingxu County, Jiancaoping District, Xinghualing District and Yangqu County, had more pronounced waves. In contrast, the virtual green water in Xiaodian District was always stable within 600 m<sup>3</sup>/kg. This study aims to provide a scientific policy recommendation for urban planning, water resources management and agricultural development in order to promote sustainable urbanization and effective water resources utilization.

**Keywords:** Water footprint, Blue water, Green water, Urbanization process, Agricultural crops