Determination Method of Water Saving Threshold in Arid Area

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Abstract

Aiming at the positive and negative effects induced by water saving measures, these two hydrological and ecological effects in arid region are analyzed in detail. Water use efficiency and underground water level are selected as two indexes to evaluate the positive and negative effects of water saving activities respectively, and then the theory value and acceptable range of suitable water saving threshold are determined. With the constructed regional hydrological model, the changes of water use efficiency and underground water level of various canals lining rate are quantified. The results show that the 34.8\% of canal lining rate is feasible water saving threshold in arid area.

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1. Introduction

Previous research focused on the saved water amount and the improvement of water use efficiency which emphasizes on the economical benefit of water saving too much, but ignores the hydrological and ecological effects of water saving measures [1-3]. In fact, large scale and high intensity of water saving measures will bring about a series of ecological issues, such as vegetation degradation, desertification of land, which is especially obvious in the arid region [4-5]. So we must reflect on the relationship between water saving intensity and economic and ecological development, and to seek a balance between them.

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2. The positive and negative effects induced by water saving measures

The circulation and flowing characteristics of water determine the water saving activities owns dual effects: positive and negative. The positive effects include: (1) Reduce water wastage, increase water use efficiency;(2) make groundwater storage capacity vacant, increase the amount of groundwater reservoir storing;(3) Control salinity, reduce soil salt accumulation, increase food production;(4) achieve rational water regulation, enhance water use benefit. The negative effects include:(1) Large-scale and high-intensity water saving measures lead to a significant decline in groundwater level and affects water use of agricultural crops in dry period;(2) the great groundwater level falling in arid areas causes shrinkage and degradation of vegetation in large area, and land intensifies desertification;(3) When groundwater level drops to a certain extent, rivers and lakes will have the anti-supply to groundwater, which results in less water in river, even drying may occur; Meanwhile, when the surface area of lakes and wetlands is reduced, the biodiversity will loss and ecological landscape tends single; (4) The upstream water consumption can increase by the improvement of water recycle rate. So with the same water conditions, the return water will reduce which not only affects the safety of river ecology, but also have a negative impact on downstream production ecology; (5) The implementation of water conservation measures may undermine the region's natural water and salt balance which may re-create habitats.

3. The determination of water saving threshold

The positive effects of saving water focus on enhancing water efficiency, which reflects the economic characteristics of water, so water use efficiency is expressed the positive effects. The negative effect of saving water mainly impacts on falling groundwater level which will cause a worsen ecosystem, so groundwater level is chosen as the negative effects. When a water saving measure implemented, the regional water use efficiency and water table is bound to change. The greater intensity of water saving will increase water use efficiency, but will also induce groundwater level fall. The Suitable water saving threshold is to find a balance point or acceptable region in these two diametrically opposed relationships, making the positive and negative effects of water saving activity in a reasonable range. In this point or range, the economic system and ecosystem use water harmoniously.

As figure 1 shows that the point O is the best threshold for water saving. At this point, the positive and negative effects are equal. The shadow AB is the feasible range for water saving. In the AO section, the groundwater level index is larger than water use efficiency index, it means the more attention for
ecosystem water use and higher ecological benefits. In contrast, in the BO section, the water use efficiency index is larger than the groundwater level index, it presents the more attention is to promote the economy development. In this section, Although the decline in groundwater levels exceeds the most appropriate value and may affect the regional ecosystem adversely, but this adverse effect is still within the acceptable range, That is the higher economic benefits is achieved by the expense part of the ecological benefit with the premise of the normal basic structure and functions of the ecosystem.

4. The case study

Taking the irrigation plain of Ningxia Hui Autonomous Region in the northwest China as the study area, the quantitative determination of the water saving threshold is discussed in this paper. Canal lining, the most important water saving engineering measures in the large irrigation area, has obvious positive and negative effects of water-saving. If canal lining rate is higher, leakage of water will be significantly reduced, and irrigation return water and water supplied to groundwater are also declined, then water tables falls which will threaten the ecosystem relied on irrigation return water and groundwater. Therefore, the appropriate lining rate must be defined on the basis of assurance water use efficiency and normal groundwater level.

Table 1. The water use efficiency and water table changes of various canal lining rates

<table>
<thead>
<tr>
<th>Lining rates</th>
<th>20%</th>
<th>25%</th>
<th>30%</th>
<th>35%</th>
<th>40%</th>
<th>45%</th>
<th>50%</th>
<th>55%</th>
<th>60%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater level changes (cm)</td>
<td>-6.7</td>
<td>-8.2</td>
<td>-10.1</td>
<td>-13</td>
<td>-16</td>
<td>-17.9</td>
<td>-20.9</td>
<td>-23.3</td>
<td>-25.2</td>
</tr>
<tr>
<td>Irrigation water use coefficient (%)</td>
<td>36.87</td>
<td>37.01</td>
<td>37.38</td>
<td>37.89</td>
<td>38.11</td>
<td>38.44</td>
<td>38.61</td>
<td>38.8</td>
<td>39.09</td>
</tr>
</tbody>
</table>

Fig. 2. The determination of water saving threshold

With the built hydrological model, the response with different canal lining rates are analyzed. The
hydrological model principles and structure can be found from the relevant literature [6]. The canal lining rate was about 13% in 2004 year, the calculated results show that the lower lining rate make the severe leakage losses and the irrigation water use coefficient is only 35.63%. The main source of groundwater are infiltration from irrigation water, so the water table fluctuations changes with the irrigation cycle. In annual winter irrigation and summer irrigation season, groundwater is very shallow with about 1m of average value. In non-irrigation period, with the large water consumption and reduction of irrigation, the shallow groundwater consumes a lot and the ground water table has decreased. Suppose that the canal lining rate attains to 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55% and 60%, the corresponding water use efficiency and water table changes are shown in Table1 and Figure 2 by application of hydrological model.

It can be seen from the figure 2, with the raise of lining rate, the groundwater level falls while the water use efficiency increase. Two curves intersect at point O, which means this point is the equilibrium point of the economic and ecological benefits with only lining measure. Also, it is the balance point for positive and negative effects of water saving. At this point, the canal lining rate is about 34.8% and the groundwater levels declines about 11.7m.

5. Conclusions

When the effects induced by a single water saving measure are evaluated, besides water use efficiency, the groundwater level, economic analysis must be considered. In this paper, water use efficiency and groundwater level are chosen as the representative indicators to measure hydrological economic and ecological benefits of water saving activities. The future study may enrich and improve the indicators so as to reflect more comprehensive hydrological response of water saving activities. To construct the appropriate feedback mechanisms, the hydrological effects of water saving is applied to water use decision-making process to promote the rational water resources allocation.

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References