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Article

Priority-Based Hedging Rules for Reservoir Water Allocation Under Drought Conditions

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Abstract: The paper compares reservoir water allocation rules under drought: the standard operating policy (SOP), one-point and seasonal hedging, and a proposed two-point hedging rule that guarantees priority for drinking water supply. Rule parameters were optimized under a drought scenario (80 % of real 2000–2001 inflow) and tested on 2002 under normal, moderate (×0.8) and severe (×0.65) drought. In terms of Hashimoto criteria, the proposed rule reduced vulnerability from 71–81 % under SOP to 35–43 %, roughly by half. The share of days with interrupted drinking water supply fell from 8.5 % to 0 % in a normal year and from 16.2 % to 7.1 % under severe drought. The price was a 24–33 % increase in total deficit volume.

Keywords: reservoir, drought, hedging rule, water allocation, priority, reliability, vulnerability.

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1. Introduction

Iqlim o'zgarishi sharoitida Markaziy Osiyoda qurg'oqchil yillar takrorlanishi ortib bormoqda. Bu esa suv omborlaridan suv taqsimlashda oldindan belgilangan qoidalarga ehtiyojni kuchaytiradi [1, 2]. Amaliyotda qo'llanadigan standart qoida (SOP) qurg'oqchilik boshlanganini sezmaydi va zaxirani tezda tugatadi. Natijada mavsum oxirida barcha iste'molchilar, jumladan aholining ichimlik suvi ta'minoti ham xavf ostida qoladi [3].

Hedjing qoidalari — zaxira kamayganda talabni oldindan qisman cheklash orqali kelajakdagi chuqur tanqislikning oldini olish usulidir [4–7]. Bu sohada bir nuqtali va ikki nuqtali hedjing qoidalari nazariy va amaliy jihatdan o'rganilgan [5, 6]. Ammo ko'p hollarda iste'molchilar ustuvorligi alohida hisobga olinmaydi. Ushbu ishda ichimlik suvining minimal sarfini kafolatlovchi ikki nuqtali hedjing qoidasi taklif etiladi. U Hashimoto ishonchlilik, tiklanuvchanlik va zaiflik mezonlari [8] bo'yicha boshqa qoidalar bilan taqqoslanadi.

2. Materials and Methods

Suv ombori va talab. Model suv ombori: NDS 415 m (95,4 mln m³), o'lik hajm sathi 390 m. Kirim oqimi — CAMELS to'plamidagi [9] 03015500 havzasining real sutkalik oqimi. Umumiy talab D_t aprel–sentyabr oylarida 18,0 m³/s, qolgan oylarda 7,9 m³/s. Uning tarkibida ichimlik suvi D_{ich} = 2,0 m³/s ustuvor iste'molchi hisoblanadi. Mavjud suv: $A_t = (S_t + Q_t\Delta t - S_{min})/\Delta t$.

Qoidalar. (1) SOP: $R_t = \min(D_t, A_t)$. (2) Bir nuqtali hedjing [5]: $A_t < D_t/k$ bo‘lsa $R_t = k \cdot A_t$. (3) Taklif etilayotgan ikki nuqtali hedjing va ustuvorlik qoidasi. Unda nisbiy zaxira $s_t = (S_t - S_{min})/(S_{max} - S_{min})$ bo‘yicha qisqartirish koeffitsiyenti aniqlanadi:

$f_t = 1$, agar $s_t \geq a_2$; $f_t = k_{min} + (1 - k_{min})(s_t - a_1)/(a_2 - a_1)$, agar $a_1 < s_t < a_2$; $f_t = k_{min}$, agar $s_t \leq a_1$, (1)

$$R_t = \min(A_t, \max(D_{ich}, f_t \cdot D_t)). \quad (2)$$

(4) Mavsumiy hedjing — (1) qoidaning varianti bo‘lib, unda yuqori chegara a_2 iyuldan keyin 0,6 ga ko‘paytiriladi. Parametrlar (k, a_1, a_2, k_{min}) to‘r usulida optimallashtirildi. Maqsad funksiyasi — nisbiy tanqislik kvadratlari yig‘indisi va ichimlik suvi uzilishlari uchun jarima. Optimallashtirish 2000–2001 yillarda kirim oqimi 0,8 ga ko‘paytirilgan qurg‘oqchilik ssenariysida bajarildi. Optimal qiymatlar: ikki nuqtali qoida uchun $a_1 = 0{,}2$, $a_2 = 0{,}8$, $k_{min} = 0{,}5$.

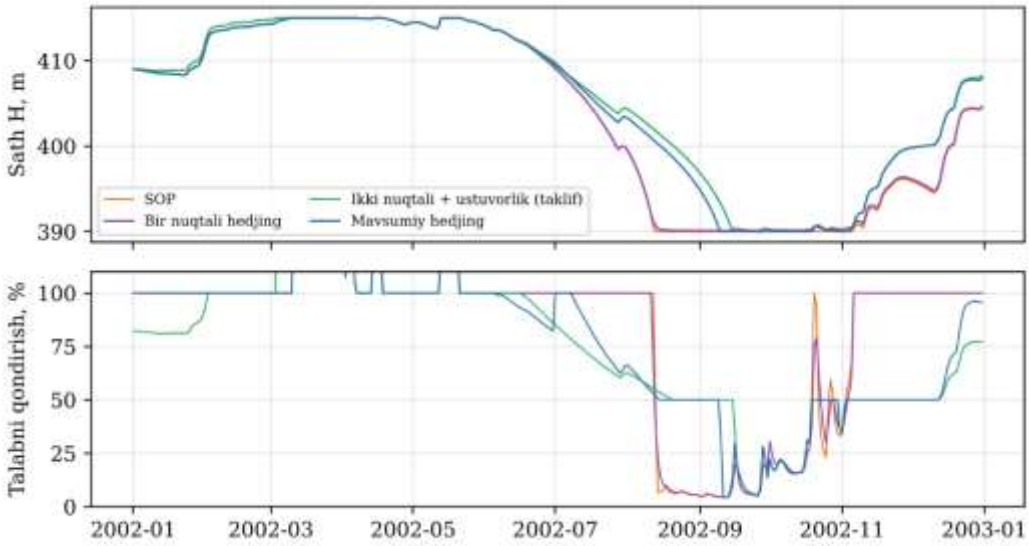
Baholash [8]: ishonchlilik (tanqisliksiz kunlar ulushi), tiklanuvchanlik (tanqislikdan chiqish ehtimoli), zaiflik (o‘rtacha nisbiy tanqislik), maksimal tanqislik, umumiy tanqislik hajmi va ichimlik suvi uzilgan kunlar ulushi. Test 2002 yilda uch ssenariyda (kirim ×1,0; ×0,8; ×0,65) o‘tkazildi.

3. Results and Discussion
Natijalar va muhokama

1-jadval. 2002 yil ssenariylari bo‘yicha natijalar (SOP / ikki nuqtali qoida)

Ko‘rsatkich	Me’yoriy (×1,0)	O‘rtacha qurg‘oqchilik (×0,8)	Kuchli qurg‘oqchilik (×0,65)
Kvadratik tanqislik	36,8 / **29,9**	48,4 / **43,2**	58,1 / **53,7**
Zaiflik, %	70,7 / **34,7**	76,3 / **38,8**	81,2 / **42,5**
Maksimal tanqislik, %	93,4 / **50,0**	94,7 / 93,7	95,7 / 94,9
Ichimlik suvi uzilishi, % kun	8,5 / **0,0**	12,6 / **3,8**	16,2 / **7,1**
Ishonchlilik, %	**81,9** / 43,3	**78,9** / 38,4	**77,0** / 36,4
Umumiy tanqislik, mln m³	**57,9** / 77,2	**73,4** / 92,9	**85,6** / 106,4

Bir nuqtali hedjing SOP dan deyarli farq qilmadi, chunki u faqat zaxira deyarli tugaganda ishga tushadi. Mavsumiy hedjing oraliq natija berdi: kvadratik tanqislik me’yoriy yilda 32,9, kuchli qurg‘oqchilikda 54,2. Eng yaxshi natijani taklif etilgan ikki nuqtali qoida ko‘rsatdi (1-jadval).



1-rasm. Kuchli qurg‘oqchilik ssenariysida (×0,65) suv sathi (yuqorida) va talabni qondirish darajasi (pastda)

1-rasmdan ko‘rinadiki, SOP va bir nuqtali qoidada suv ombori avgust o‘rtasida o‘lik hajmgacha bo‘shaydi. Shundan keyin talab atigi 5–10 % ga qondiriladi. Ikki nuqtali qoida esa zaxira 80 % dan kamaya boshlagan iyul oyidayoq chiqimni talabning 50–80 % igacha kamaytiradi. Natijada suv ombori sentyabrgacha ishlaydi va qondirish darajasi 50 % dan pastga tushmaydi. Shu tufayli zaiflik barcha ssenariylarda taxminan ikki baravar kamaydi (71–81 % → 35–43 %). Ichimlik suvi uzilishlari me’yoriy yilda butunlay bartaraf etildi, kuchli qurg‘oqchilikda esa 2,3 baravar qisqardi.

Hedjingning narxi — ishonchlilik pasayishi va umumiy tanqislik hajmining 24–33 % ga oshishi. Ya’ni chuqur va qisqa tanqislik o‘rniga sayozroq, lekin uzoqroq davom etadigan cheklov qo‘llanadi. Umumiy hajmning oshishi suv omborida mavsum oxirida ehtiyot zaxirasi qolishi bilan bog‘liq. Bu zaxira keyingi yilning qurg‘oqchil bo‘lishi xavfiga qarshi sug‘urta vazifasini bajaradi [6]. Kuchli qurg‘oqchilikda maksimal tanqislik ham 95 % ga yaqin bo‘lib qoldi. Bu shuni ko‘rsatadiki, juda kam suvli yillarda faqat qoidalar yetarli emas va qo‘shimcha choralar (ekin maydonlarini qisqartirish, suvni tejovchi texnologiyalar) zarur.

4. Conclusion

1. Qurg‘oqchilik sharoitida suv omboridan suv taqsimlash uchun ichimlik suvi ustuvorligini kafolatlovchi ikki nuqtali hedjing qoidasi taklif etildi. Uning parametrlarini qurg‘oqchilik ssenariysida optimallashtirish tartibi ishlab chiqildi.

2. Taklif etilgan qoida SOP ga nisbatan zaiflikni taxminan ikki baravar (71–81 % → 35–43 %) kamaytirdi. Ichimlik suvi uzilishlarini me’yoriy yilda 8,5 % dan 0 % gacha, kuchli qurg‘oqchilikda 16,2 % dan 7,1 % gacha qisqartirdi.

3. Hedjing umumiy tanqislik hajmini 24–33 % ga oshiradi. Shu sababli qoidani tanlashda tanqislik chuqurligi va davomiyligi o‘rtasidagi kelishuvni suv iste’molchilari bilan birgalikda belgilash tavsiya etiladi.

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