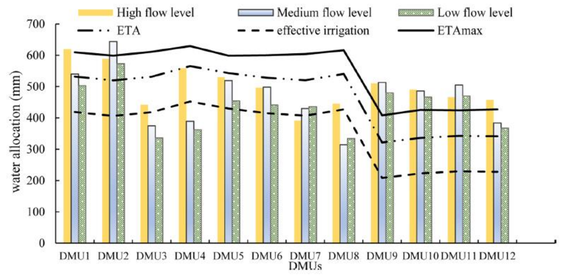
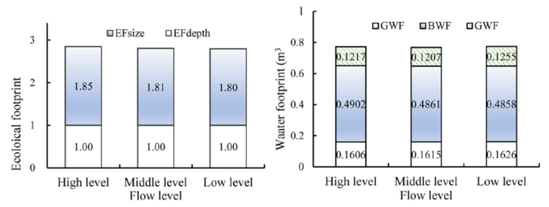
Study on synergistic development mode across water, energy, food and ecology for drogught irrigation district under uncertainties

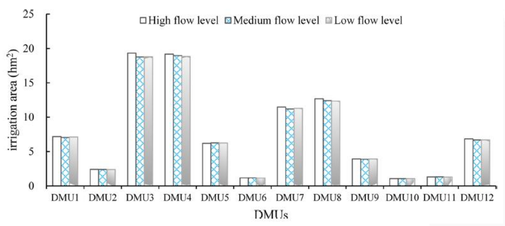
Youzhi Wang, Qiangkun Li, Wenge Zhang, Huijuan Yin
Yellow River Institute of Hydraulic Research, Yellow River Conservancy Commission, Zhengzhou 450003, China
Key Laboratory of Water and Soil Conservation in the Loess Plateau, MWR, Zhengzhou 450003, China

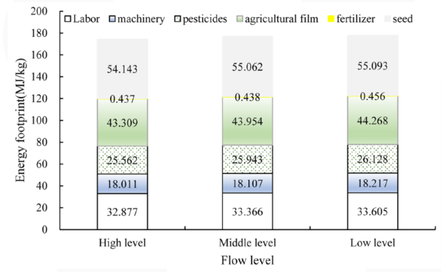
Objectives

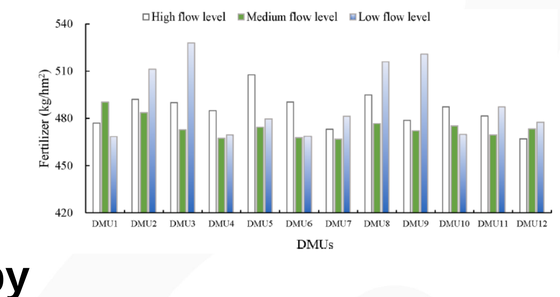
In order to achieve synergistic development of water-energy-food-ecology development, this paper identifies connections and feedbacks among water-energy-food-ecology system. Besides, randomness of hydro-meteorological elements is measured by stochastic programming and other uncertain programming. Moreover, the multi-objective programming is developed by maximizing yield, water saving, ecological protection and minimizing energy consumption. It can provide multiple groups of water allocation plans for managers. Compared with other studies, it has advantages in building connections of elements of the synergistic system, and reaching tradeoff amid water saving, energy consumption, food and ecological safety. The model is used to drought irrigation district to verify its application, and proved to be an effective tool to support sustainable development of the water-energy-food-ecology.

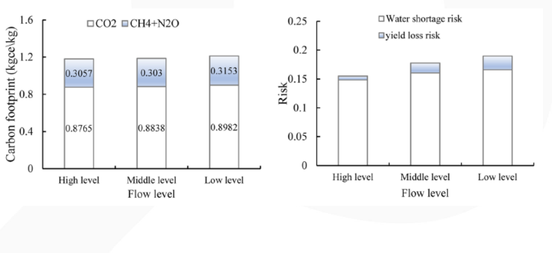












Methods

1Sustainable development model based on information entropy

$$S = -\frac{1}{\ln n}\sum_{i=1}^{n}(q_{ij}/q_j)\log(q_{ij}/q_j) \qquad q_j = \sum_{i=1}^{n} q_{ij}\,(i = 1,2,...,n;\ j = 1,2,...,m)$$

$$y = a - x^3 \qquad y = x^{\eta} \qquad b = \begin{cases} 1/\eta & \eta > 1 \\ \eta & \eta \le 1 \end{cases}$$

2 multi-objective programming

$$f_1 = \min EF_{3D} = EF_{depth} \times EF_{size}$$

$$f_2 = \min \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{h=1}^{H} p_h\left(WF_{green,ijh} + WF_{blue,ijh} + WF_{grey,ijh}\right)$$

$$f_3 = \min \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{h=1}^{H} p_h\left(EF_{W,ijh} + EF_{M,ijh} + EF_{L,ijh} + EF_{F,ijh} + EF_{P,ijh}\right)$$

$$f_4 = \min \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{h=1}^{H} p_h\left(CF_{F,ijh} + CF_{I,ijh} + CF_{M,ijh} + CF_{L,ijh} + CF_{S,ijh}\right)$$

Results

1 Sustainable degree

Water-food-energy system presents increasing tendency, and increased rate is 0.02/a, and harmonious degree of coordinated system becomes better. The development degree, coordinated degree and health degree of arbitrary two systems own different variations.

2 Optimal results

Optimal water allocation schemes present spatially-distributed characters. Irrigation area of the seed corn is biggest for all crops. Optimal fertilizer allocation tends to minimum fertilizer because of low GHG emission. Ecological footprint under three hydrological years were all smaller than ecological capacity.

Conclusions

This paper measures the sustainable state of water-food-ecology system by building development degree, harmony degree and health degree.

The optimal water allocation, irrigation area allocation and fertilizer allocation schemes could be obtained by developing footprint based multi-objective programming under uncertainties, and it is proved to be an effective tool to support resources allocation.

More uncertain parameters should be identified and characterized to improve robustness of decisions.