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A developed fuzzy-stochastic optimization for coordinating human activity and eco-environmental protection in a regional wetland ecosystem under uncertainties

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ABSTRACT

In this study, a developed fuzzy approximation mixed stochastic approach (DFAS) is proposed for a regional wetland ecosystem (RWE) management under uncertainty. DFAS can handle traditional objective non-determinacy (caused by natural element) and anthropogenic uncertainty (caused by artificial factor) expressed as probability distribution and fuzzy set in objective function or constraint; it also extend to reflect compromise of risk attitude/preference of the decision maker in decision-making process through introducing rough set theory (RST) and measure Me. The proposed approach can be applied to a practical RWE management of Yongnianwa wetland, located in north of China, where the natural ecosystem has been suffered severe degradation induced by disharmonious developing speeds between human activities and environment. Results of ecological effects of wetland ecosystem, water allocation patterns, pollution-mitigation schemes, and system benefit analysis can be acquired. The results indicate that wetland ecosystem can produce a numbers of positive effects to the pollution control and environmental protection, where the total excess pollution discharges (concluding TN, TP and BOD) would reduce 202 and 242 tone (LAV and UAV) at highest. Meanwhile, it finds that wetland system method deemed as an effective/appropriate technology can remove 67%, 72% and 88% TN, TP and BOD from wastewater, where water quality standard of effluent would be II, II and III for TN, TP and BOD at best. However, competitive relationships between water consumption from human activity and wetland protection can facilitate decision makers adjusting current water-environment policies with a more efficient/sustainable manner. Meanwhile, tradeoffs between economic benefit and system-failure risk under optimistic/pessimistic option can support generating a robust plan associated with risk control for RWE under uncertainties. All of these detections can avail local decision makers to generate a plan integrating socio-economic development and eco-environmental protection sustainably.

1. Introduction

In recent years, an eco-crisis due to ecosystem degeneration and human activity expansion has been of concern to many researchers and managers worldwide. Numbers of projects or ecological engineer techniques for recovering ecological functions have been carried out, which is perceived to produce significant effects on eco-crisis in the context of accelerated industrialization, urbanization, population growth today (Mensing et al., 1998). In general, numerous ecological engineer techniques can combine economic development and eco-environmental protection based on self-design and self-organization principle to intend a sustainable ecosystem for the benefit of both

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Nomenclature

WM_{tm}	Expected developing scale for municipality in period t (m^3)
φ_{tm}	The coefficient of water consumption per person for resident sector of municipality in period t (m^3/p)
rm_{tm}	Water consumption per area for municipal services sector in municipality (m^3/ha)
B_{tm}^{M}	Unit benefit of water demand for municipality being delivered in period t ($\$/m^3$)
Y_{tm}^{M}	Unit water-supply cost for municipality when a volume of water being delivered in period t ($\$/m^3$)
p_{tmp}	Probability for occurrence of scenario *p* during period *t* (%)
L_{tm}^{M}	Unit loss for municipality when a volume of water not being delivered in period t ($\$/m^3$)
SM_{tm}	Water shortage for municipality in period t (m^3)
WA_{tn}	Expected irrigation area for agricultural crop m in period t (ha)
ra_{tn}	Water consumption per irrigation area for agricultural crop m in period t (m^3/ha)
RHA_{tn}	Water consumption per unit area for agricultural crop in period t (m^3)
B_{tn}^{A}	Unit benefit of water demand for agricultural crop being delivered in period t ($\$/m^3$)
Y_{tn}^{A}	Unit cost for agricultural crop when a volume of water being delivered in period t ($\$/m^3$)
L_{tn}^{A}	Unit loss for agricultural crop when a volume of water not being delivered in period t ($\$/m^3$)
SA_{tn}	Water shortage area for agricultural crop in period t (m^3)
WE_{tk}	Expected area for ecological type n in period t (ha)
re_{tk}	Water consumption per ecological area for ecological type n in period t (m^3/ha)
B_{tk}^{E}	Unit benefit of water demand for ecology being delivered in period t ($\$/m^3$)
Y_{tk}^{E}	Unit cost for ecology when a volume of water being delivered in period t ($\$/m^3$)
L_{tk}^{E}	Unit loss for ecology when a volume of water not being delivered in period t ($\$/m^3$)
SE_{tk}	Water shortage for ecology in period t (m^3)
WI_{ti}	Expected developing scale (person) for tourist in period t (p)
MWI_{ti}	The maximum expected developing scale (person) for tourist in period t (p)
η_{ti}	The coefficient of water consumption per person for tourism in period t (m^3/p)
B_{ti}^{I}	Unit benefit of water demand for tourist being delivered in period t ($\$/m^3$)
Y_{ti}^{I}	Unit cost for tourist when a volume of water being delivered in period t ($\$/m^3$)
L_{ti}^{I}	Unit loss for tourist when a volume of water not being delivered in period t ($\$/m^3$)
SI_{ti}	Water shortage for tourist in period t (m^3)
LCM_{tm}	Total sewage treatment cost for municipality irrespective of ecological effect in period t ($)
C_{tm}^{M}	Unit sewage treatment cost for municipality if pollution discharge being retreated by traditional sewage disposal plant in period t ($\$/m^3$)
DM_{tm}	Total capacity of sewage purification for municipality through ecological mechanism in period t (m^3)
DM_{tm}^{N}	The purification capacity of TN discharge for municipality through ecological mechanism in period t (m^3)
DM_{tm}^{P}	The purification capacity of TP discharge for municipality through ecological mechanism in period t (m^3)
DM_{tm}^{B}	The purification capacity of BOD discharge for municipality through ecological mechanism in period t (m^3)
R_{tm}^{M}	Unit benefit of sewage purification for municipality through ecological mechanism in period t ($\$/m^3$)
C_{tm}^{MN}	Unit sewage treatment cost for municipality if TN discharge being retreated traditional sewage disposal plant in period t ($\$/m^3$)
C_{tm}^{MP}	Unit sewage treatment cost for municipality if TP discharge being retreated traditional sewage disposal plant in period t ($\$/m^3$)
C_{tm}^{MB}	Unit sewage treatment cost for municipality if BOD discharge being retreated traditional sewage disposal plant in period t ($\$/m^3$)
PNM_{tm}	TN discharge rate of per water consumption for municipality in period t (ton/m^3)
PPM_{tm}	TP discharge rate of per water consumption for municipality in period t (ton/m^3)
PBM_{tm}	BOD discharge rate of per water consumption for municipality in period t (ton/m^3)
LCA_{tn}	Total sewage treatment cost for agricultural irrigation irrespective of ecological effect in period t ($)
C_{tn}^{A}	Unit sewage treatment cost for agricultural irrigation if pollution discharge being retreated by traditional sewage disposal plant in period t ($\$/m^3$)
DA_{tn}	Total capacity of sewage purification for agricultural irrigation through ecological mechanism in period t (m^3)
DA_{tn}^{N}	The purification capacity of TN discharge for agricultural irrigation through ecological mechanism in period t (m^3)
DA_{tn}^{N}	The purification capacity of TP discharge for agricultural irrigation through ecological mechanism in period t (m^3)
DA_{tn}^{N}	The purification capacity of BOD discharge for agricultural irrigation through ecological mechanism in period t (m^3)
R_{tn}^{A}	Unit benefit of sewage purification for agricultural irrigation through ecological mechanism in period t ($\$/m^3$) in period t ($\$/m^3$)
C_{tn}^{AN}	Unit sewage treatment cost for agricultural irrigation if TN discharge being retreated traditional sewage disposal plant in period t ($\$/m^3$)
C_{tn}^{AP}	Unit sewage treatment cost for agricultural irrigation if TP discharge being retreated traditional sewage disposal plant in period t ($\$/m^3$)
C_{tn}^{AB}	Unit sewage treatment cost for agricultural irrigation if BOD discharge being retreated traditional sewage disposal plant in period t ($\$/m^3$)
PNA_{tn}	TN discharge rate of per water consumption for agricultural irrigation in period t (ton/m^3)