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Modeling the scenarios of wetland restoration in Hengshui Lake National Nature Reserve

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Abstract

Hengshui Lake National Nature Reserve is one of most ecologically valuable freshwater wetlands in northern plain of China, providing crucial staging and wintering habitats for a large variety of endangered waterbirds. However, this unique wetland has been suffered from serious habitat fragmentation and ecological function degradation due to increased socioeconomic activities within and surrounding the nature reserve. Aiming at enhancing its ecological function while balancing the needs between the conservation priorities and indispensable socioeconomic activities, three landuse scenarios of wetland restoration were proposed based on the different magnitude of wetland restoration. In this study, a physiotopes was used as planning unit which was defined as the combinations of landuse/landcover types and topographic factors (i.e.water level, slope) with RS & GIS techniques. The pros and cons of the scenarios were evaluated based on its ecological feasibility and practical applicability. The results provided the basis for adopting the measures of wetland restoration and consequent landuse adjustment, finally potential impacts and the practical suggestions for the wetland restoration and habitat modification in Hengshuilake NNR were thus forwarded and discussed.

Key words: wetland restoration; scenario; Hengshui Lake

1. Introduction

The theories and methodologies of wetland restoration and rehabilitation and its effectiveness assessment have been hot issues in research field of wetland ecology（Findlay,2002；Zedler,2000；Kenthla,2000；Richardson *et al*.,2005;Stokstad,2005). In view of crucial realities of wetland damage and degradation in China, the government and academic circles have paid high attentions to wetland conservation and restoration by initiating and implementing a lot of long-term and national-scale projects of wetland conservation and restoration successively (State Forestry Adminstration,2000). However, due to lack of relevant scientific basis and effective technical support, many ongoing wetland projects have ignored ecological and hydorogeomophic features and socioeconomic context , and one single restoration scheme always can hardly serve for complicated decision making covering

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ecological and socioeconomic targets., Though as one of the most valuable freshwater wetland in north china plain, Hengshui Lake has been suffered from serious habitat fragmentation and ecological function degradation due to increased human activities within and surrounding the nature reserve. Aiming at enhancing its ecological performance while balancing the needs between the conservation priorities and indispensable socioeconomic activities, we elaborated three scenarios of wetland restoration schemes considering the different scopes and magnitude of wetland restoration, we identified the measures to realize the scenarios and modelled resulted wetland landscape and landuse types spatial explicitly by using GIS technique, this research is expected to provide a methodology and tool to develop restoration schemes for wetland restoration.

2. Study Area

Hengshui Lake national nature reserve has been established in 2002 aiming at conserving endangered waterbirds and associate freshwater habitats (fig.1), which is regarded as the most ecologically valuable freshwater ecosystem in North China Plain with a vast area of reed marsh. The total area of the reserve is 265.25km2, with its maximum water storage capacity of 1.88 billion m3. The nature reserve provides wintering and perch habitats for a verities of endangered waterbirds, especially acting as the most important wintering habitat for grey crane. In addition, Hengshui lake also has special socioeconomic significance as it has been designated as a key hub of middle route for world largest water project, i.e., the South-to-North Water Diversion Project (SNWDP), which nevertheless will greatly favor for its wetland development besides those socioeconomic benefits, therefore the wetland restoration in Hengshui Lake can be supported by adequate water resources from SNWDP.

3. Data and Methods

The land use/land cover data of Hengshui Lake NNR was obtained by SPOT5 image in 2003, in which the vegetation and land cover types were extracted and rectified according to the field verification. DEM elevation data for surface features was acquired from two sources, of which Landform data were digitized and generated by topographic maps with1:10,000 scale provided by the nature reserve, underwater topographic map were generated by extrapolating point-count surveying data of water depth in Hengshui Lake. The abiotic condition and land cover types were classified to facilitate habitat description and suitability analysis. All these data were transformed into grid-based GIS format with resolution of 30m * 30m. he habitat requirements and other biodiversity data were

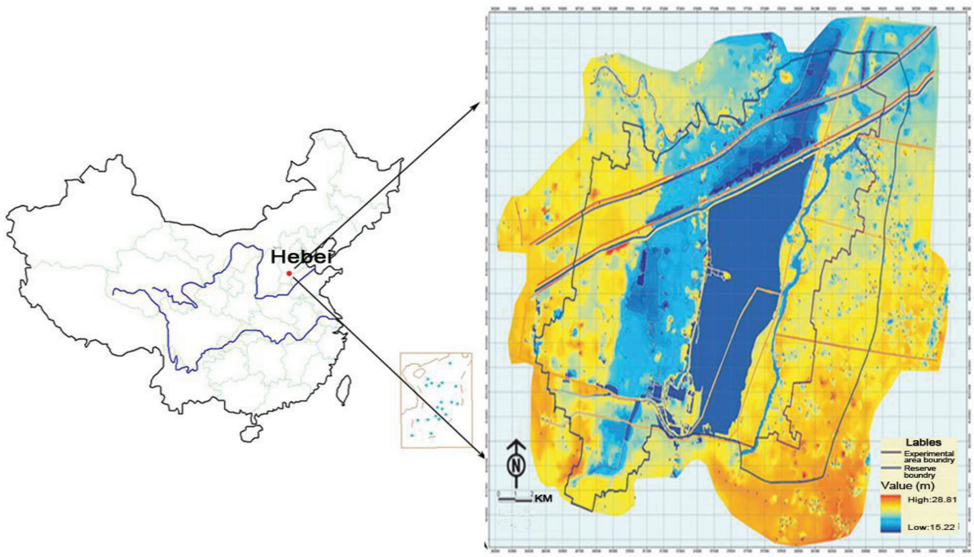

Fig.1. study area of Hengshui Lake National Nature Reserve

mostly informed by the monitoring program of nature reserve, expertise inquiring and documented literature.

In this research, ecotopes were employed in defining the habitat suitability of focal species, which can be regarded as a basic unit of landscape structure, composing of abiotic and biotic elements on site. To facilitate the habitat suitability analysis, ecotopes were simplified as physiotopes and land cover types (or vegetation types). Physiotopes refers to the abiotic condition in site level (Harms 1995). As the abiotic condition of Hengshui Lake is mainly shaped by site-based water level and landform, this two factors were chosen and combined to define the physiotopes with their different combinations (table 1).The methodology of defining habitat suitability based on the concept of ecotope can be referred by the similar previous research of Zhangdu Lake (Li et al 2005).

The method of scenario design can be demonstrated by the following procedures(fig.2):1) Through submerging modeling and considering associated ecological and socioeconomic impacts, the multi-target scenarios could be identified addressing different goals such as water storage and flood control, biodiversity conservation and eco-agricultural landuse; 2) Based on habitat suitability analysis, the potential target physiotopes in different water level and slope can be developed respectively, and the potential target ecotopes could be definded.3) With overall considerations of restoration feasibility and the characteristics of each function divisions in NNR, the target ecotopes of each scenario were accommodated and decided by comparing existing ecotope and its potential target.4) By confronting target ecotopes with existing situation, the measures to realize the different desired targets with knowledge-based system and its spatial location thus can be elaborated(table 2).

Table.1. The classification of physiotopes in Hengshui Lake wetland

Water level H/m	Gentle slope(0°~10°)	Medium slope（10°~35°）	steep slope（35°~60°）
Deep water area （H>0.5）	Gentle-slope deep water area	Medium-slope deep water area	steep-slope deep water area
Shallow water area(0<H<0.5)	Gentle-slope shallow water area	Medium-slope shallow water area	steep-slope shallow water area
Fluctuating belt (-2<H<0)	Gentle-slope fluctuating belt	Medium-slope fluctuating belt	steep-slope fluctuating belt

Table.2. The classification of physiotopes in Hengshui Lake wetland

Physiotope	natural water area		reed mush		farmland		habitation area	
	Target physiotope	measures	Target physiotope	measures	Target physiotope	measures	Target physiotope	measures
Gentle-slope deep water area	Open water	Intact	open water	dredging	open water	returning woodland/farmland to lake	open water	ecological migration
Gentle-slope shallow water area	open water	dredging	shallow swamp	Intact	shallow swamp	returning woodland/farmland to lake	open water	ecological migration
Gentle-slope fluctuating belt	gentle-slope shoals	water level control	shallow swamp	water level control	open water	returning woodland/farmland to lake	gentle-slope shoals	ecological migration and slope modification
Medium-slope deep water area	open water	Intact	open water	dredging	open water	returning woodland/farmland to lake	open water	ecological migration
Medium-slope shallow water area	open water	gentle-slope shoals	shallow swamp	gentle-slope shoals	open water	returning woodland/farmland to lake and slope modification	open water	ecological migration and slope modification

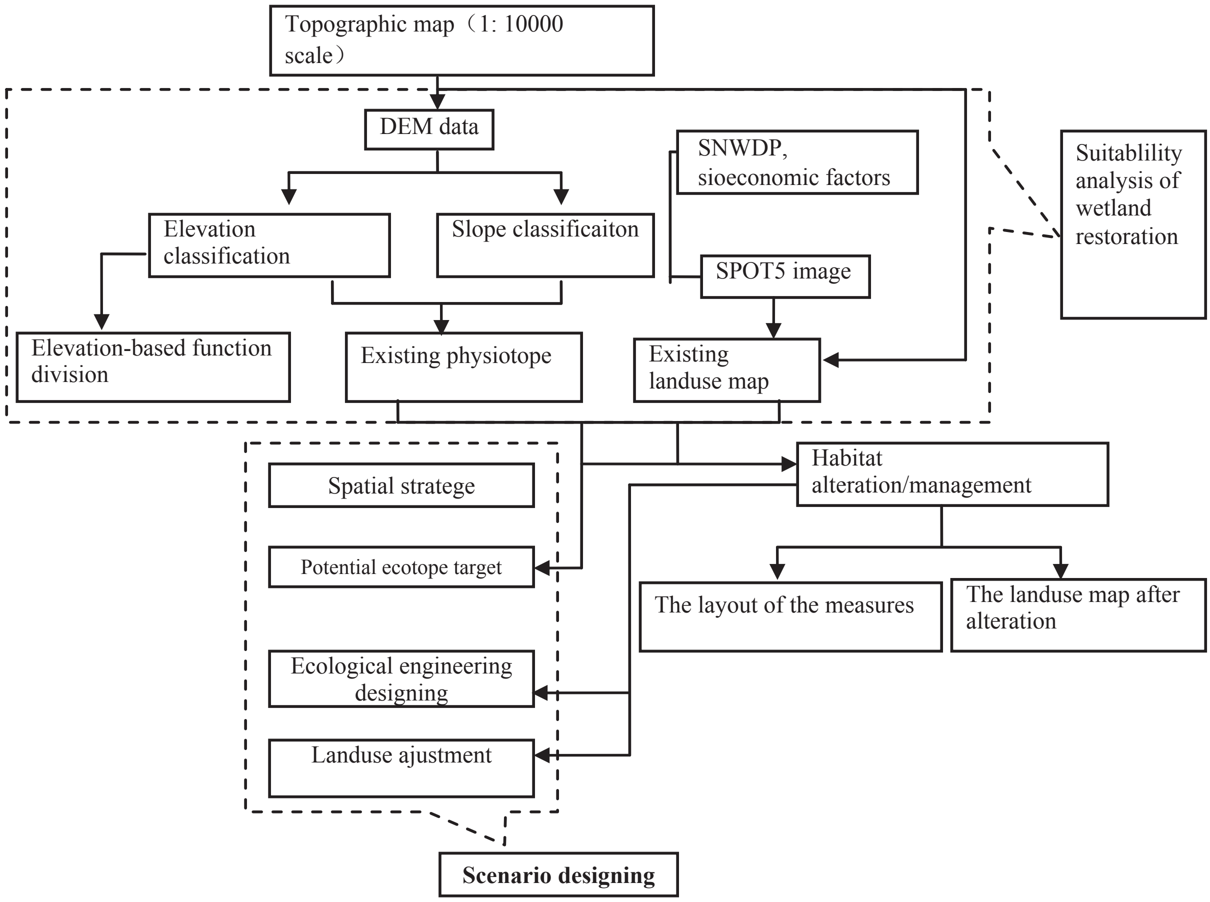

Fig.2. The flow chart of wetland restoration and habitat alteration in Hengshui Lake

Hydro-monitoring data showed that the average water level fluctuated between 19~21m (Huanghai Elevation System, HES), while the original design criteria is 21m. Our GIS simulation analysis for submerging analysis indicated that the restoration water level of main part of Hengshui Lake would be appropriate to be set at 21m considering the constraints of socioeconomic loss (e.g. loss of cultivated landuse, immigration etc) in comparison with its lower level at 19m, therefore, three scenarios of wetland restoration can be elaborated following:

Wetland Restoration Scenario (WRS): Addressing wetland restoration instead of habitat alteration. Both the eastern and western parts of lake would be restored to 21m at water level, lakeshore within 19.5~21m would be seasonally submerged by water level control to enhance its ecological functioning.

Habitat Alteration Scenario (HAS): Focusing on habitat alteration instead of wetland restoration. The water level of eastern(main) parts of lake would be raised to 21m, maintaining fluctuating lakeshore between 19.5~21m, intervened with habitat management approaches; the western part and north part to Fuyang cannel would be restored mainly through the measures of habitat modifications.

Restoration and Alteration Scenario (RAS): Paying equal attention to habitat alteration and wetland restoration. The water level of eastern part would be controlled at 21m, while keeping hydro-fluctuations between 19.5~21m; other parts would remain intact.

4. Results

Based on the different combinations of physiotope and landuse/landcover types, the existing habitat suitability units (i.e. ecotope) of Hengshui Lake can be spatial explicitly generated by GIS, and those target ecotopes can also be modeled respectively (fig.3),

By contrasting target ecotope units with that of existing situation, the measures were identified, which can lead existing situation to desired landscape target, Fig.4 showed and located measures for the different scenarios. It revealed that the habitat area needed to be altered in WRS (scenario 1) would be least compared to the other two scenarios, and the measures would be mainly needed in northern parts and its eastern and western sub-lakes. The results showed that HAS (scenario 2) would present the largest altered area of habitat units in upland and lakeshore higher than 21m, modified by the measures and management types such as planting restructuring, dredging and revegetation, etc. RAS (scenario 3) stood the medium at its altered habitat area mainly produced by wetland restoration at lower lakeshore, the intervening measures mainly include dredging, foraging habitat building, planting restructuring, etc. In generally, the key measures to realize the scenarios can be identified as returning farmland to lake, slope modification and dredging. Fig.5 showed modified landuse of the scenarios resulted from the measures and management types, Table 3 provides details on magnitude (area) of target habitat units and measures for the different scenarios.

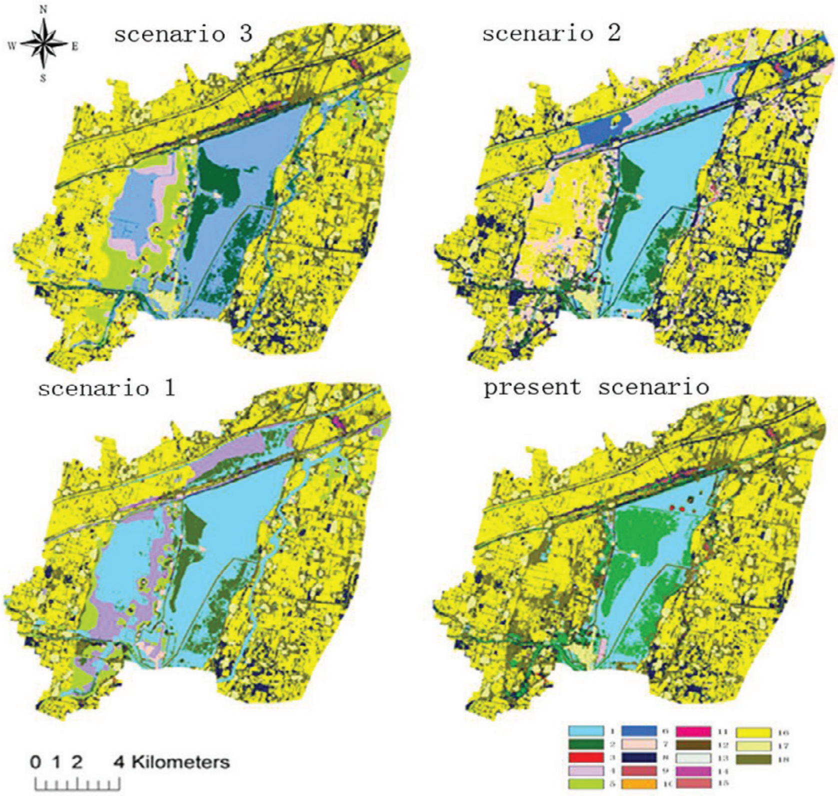

Fig.3. spatial explicit map of wetland restoration and habitat alteration target units (1-shallow open water(including artificial water),2-shallow swamp, 3-chinese tamarisk, 4-gentle-slope shoals, 5-meadow,6-grass, 7-wild farmland, 8-woodland(i.e. economic forests, protection forests and slope protection shrubs),9- Suaeda,10-medium-slope open water, 11-medium-slope shallow swamp,12- medium-slope shoals, 13- medium-slope meadow, 14-steep-slope open water, 15- steep-slope shoals, 16-eco-agricutural land,17-ecological town,18-bare land）

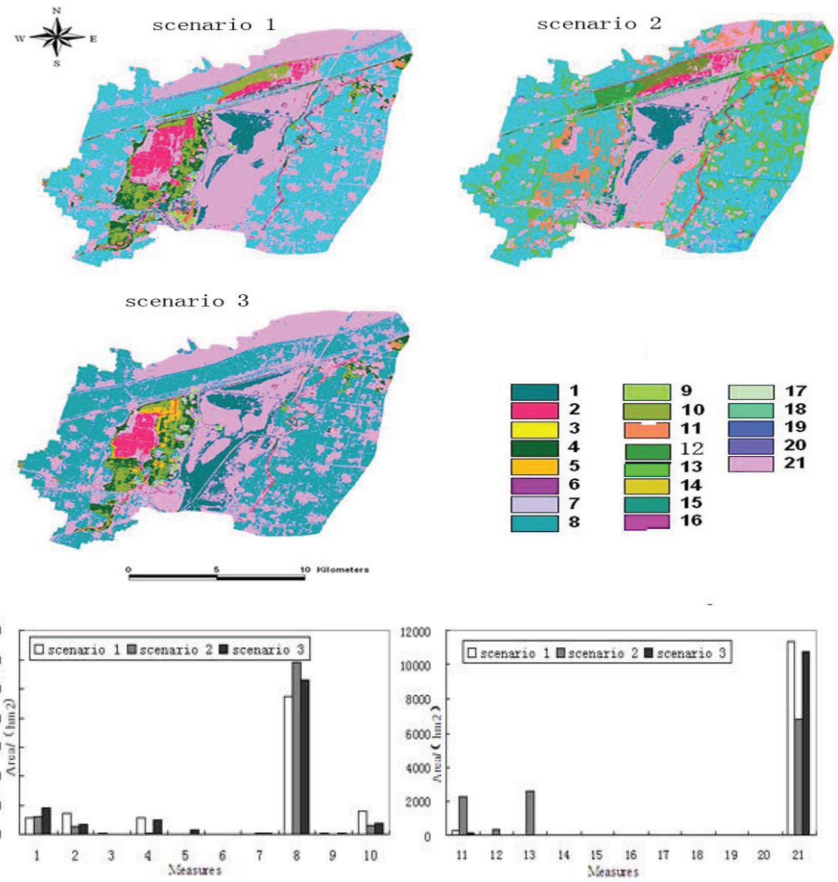

Fig.4. measures and their spatial scopes of each scenario (1-dredging, 2-returning woodland/farmland to lake,3-ecological migration,4-water level control,5-returning woodland/farmland to lake and water level control,6- ecological migration and water level control, 7-soil borrowing, 8-planting restructuring, 9-building foraging land, 10-returning woodland/farmland to grass and water level control, 11-ecological migration and revegetation, 12-returning woodland/farmland to grass, 13- revegetation, 14-slope modification,15-returning woodland/farmland to lake combined with slope modification, 16- ecological migration and slope modification,17-water level control and slope modification, 18- returning woodland/farmland to grass and slope modification, 19- water level control, revegetation and slope modification, 20-revegetation and slope modification, 21-retaining originally）

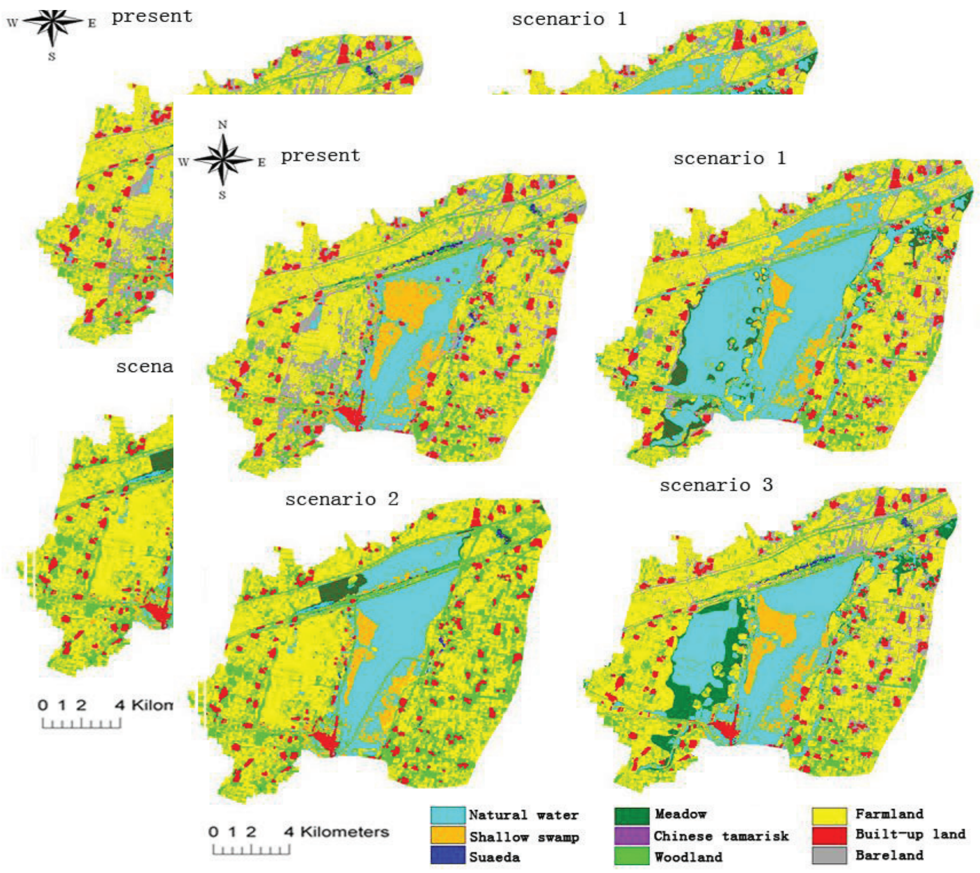

Fig.5. landuse distributions of wetland restoration scenarios

Table.3. Landscape targets (ecotopes), measures and altered areas for the scenarios

Landscape target	Area		Measures
Shallow open water	Scenario1	5875.75 hm^2	Dredging, returning woodland/farmland to lake, ecological migration
	Scenario 2	3870.66hm^2	Dredging, returning woodland/farmland to lake, ecological migration, soil borrowing
	Scenario 3	4377.74hm^2	Dredging, returning woodland/farmland to lake, ecological migration, soil borrowing
Shallow swamp	Scenario 1	1517.67 hm^2	Returning woodland/farmland to lake、ecological migration
	Scenario 2	1621.89hm^2	Slope modification, returning woodland/farmland to lake, ecological migration
	Scenario 3	1858.25hm^2	Returning woodland/farmland to lake, ecological migration, slope modification, returning woodland/farmland to lake and slope modification, ecological migration and slope modification
Tamarisk shrub	Scenario 1	5.12 hm^2	Intact
	Scenario 2	12.15hm^2	Intact
	Scenario 3	9.77hm^2	Intact
Gentle-slope shoals	Scenario 1	1932.91 hm^2	Returning woodland/farmland to lake, ecological migration
	Scenario 2	663.59hm^2	Returning woodland/farmland to lake, returning woodland/farmland to lake and

			slope modification ecological migration, ecological migration and slope modification
	Scenario 3	684.58hm^2	Returning woodland/farmland to lake, returning woodland/farmland to lake and slope modification ecological migration, ecological migration and slope modification
Meadow	Scenario 1	1044.04hm^2	Intact
	Scenario 2	0.72hm^2	Slope modification
	Scenario 3	1534.05hm^2	Ecological migration and revegetation、ecological migration and slope modification, revegetation and slope modification、returning woodland/farmland to grass and slope modification
Grass	Scenario 2	428.64hm^2	Revegetation, returning woodland/farmland to lake
	Scenario 3	0.01hm^2	Revegetation, returning woodland/farmland to lake, ecological migration and revegetation
Wild farmland	Scenario 1	139.45hm^2	Intact
	Scenario 2	2175.14hm^2	Building foraging land
	Scenario 3	84.9hm^2	Building foraging land
Woodland	Scenario 1	2599.46 hm^2	Planting restructuring
	Scenario 2	5147.91hm^2	Planting restructuring
	Scenario 3	2377.66 hm^2	Planting restructuring
Suaeda grassland	Scenario 2	104.05 hm^2	intact
	Scenario 3	114.86 hm^2	intact
Eco-agricultural land	Scenario 1	9422.71 hm^2	Planting restructuring
	Scenario 2	10843.8hm^2	Planting restructuring
	Scenario 3	11268.35	Planting restructuring

5. Conclusion and discussion

In this research, scenario approach was employed as a useful tool for ecological planning of wetland restoration in a human-dominated area, i.e. Hengshui Lake NNR, in which Wetland restoration and habitat alteration are regarded as two optional directions of wetland mitigation to balance socioeconomic needs and wetland conservation. **Wetland Restoration Scenario (WRS)** aims at restoring hydrological linkage among eastern, western and northern parts of Hengshui Lake NNR, in which some measures should be taken to alter the existing ecotopes, such as water level control, returning agricultural and to the lake and dredging. In addition, the adjacent area to the wetland region would be rehabilitated by some specific management types such as human disturbance alleviation and non-point pollution control, etc. WRS may only be realized with water supply from central line of South-to-North Water Diversion Project, representing the ecological-oriented natural development for Hengshui Lake NNR. While **Habitat Alteration Scenario (HAS)** addresses enhancement of wetland ecosystem function and habitat quality mainly by the measures of habitat alteration, still maintaining the water storage function of main (eastern) part of Hengshui lake by shaping more fluctuating lakeshore, this would need to take measures such as slope modification, revegetation, plant restructuring and building foraging land, etc. The magnitude of wetland restoration and habitat alteration would be constrained by existing water storage capacity. The habitat alteration would be mainly located at farmland of western part of reserve, especially the core zone of the nature reserve would be taken the measures of transmigrant combined with some management types, this scenario will have the lowest cost without large-scale water level restoration. **Restoration and Alteration Scenario (RAS)** explored integrating the advantages of HAS and RAS. In this integrated scenario, the eastern, western and northern parts of Hengshui Lake would be hydrologically connected by large-scale water level restoration coupled with measures of habitat modification such as shaping fluctuating lakeshore. Water gate eco-control would be implemented to restore its natural hydrological regime. Transmigrant may be needed at core zone and restoration area. The habitat types can be diversified by those measures for wetland restoration, habitat alteration and management, resulting superior habitat quality to the HAS and RAS, but the socioeconomic cost of this scenario would be highest nearly the total of HAS and RAS.

These three scenarios were elaborated to represent different directional restoration goal, and managed to minimize involvement of transmigrant due to the heavy constraints of socioeconomic context. It is difficult to definitely affirm the which one is best among the scenarios, three scenarios will have their irreplaceable value corresponding to the different possible socioeconomic context though they may have their advantage and disadvantage in a certain decision making context. Indeed, the value of scenario approach consists in providing a scientific basis and more flexible options for us to cope with uncertainty in future decision making circumstance.

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