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Abstract

Land use/cover change is a major factor for global change because of its interactions with climate, ecosystem processes, biodiversity, and, even more important, human activities, research on land use/cover change has become an important aspect of global change. The present research paper aims to investigate the land use changes over the time period, 2005 to 2014, in the Ousteri wetland. The information collected through the ecological, hydrological and geological analysis was used to carry out the quantitative research on Ousteri wetland land use/cover change. The temporal changes of land use characteristics were quantitatively analyzed and then the driving forces of land use changes were examined based on natural and artificial factors. As the result of natural factors and human disturbances, the area of wetland shrunk, bringing the conversion from wetland to terrestrial land use type. The annual conversion rates indicated the land use changes in Ousteri wetland.

Keywords: *Land use cover, Ousteri wetland, Dynamic Degree model, Ecosystem modification*

JEL Codes: *O13, Q15, Q56, N55, R11*

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INTRODUCTION

Land use/cover change is a major factor for global change because of its interactions with climate, ecosystem processes, biogeochemical cycles, biodiversity, and, even more important, human activities (Vogelmann and Howard, 1998; Xiao *et. al.*, 2006), research on land use/cover change has become an important aspect of global change. Geographic information system (GIS) have been widely applied in identifying and analysing land use/cover change.

GIS can provide multi-temporal data that can be used to quantify the type, amount and location of land use change. GIS also provides a flexible environment for displaying, storing and analysing digital data necessary for change detection (Wu *et. al.*, 2006). Wetlands are integral part of the global ecosystem as they can prevent or reduce the severity of flood, feed ground water, and provide unique habitats for flora and fauna (Zhang *et. al.*, 2009). With the development of social economy, human activities (urbanization, deforestation, agriculture reclamation, etc.), as external stress factors, is accelerated the wetland landscape change such as area shrinking, landscape fragmentation and ecological function degradation (Yu *et. al.*, 2010). This, in turn, influences the regional hydrological environment, climate change, biodiversity and so on (Xiao *et. al.*, 2010). In this way, land use/cover changes in wetland region play an important role on wetland ecological environment and global environmental change.

Ousteri wetland, which is an inter-state wetland, spread partly in Puducherry and partly in Tamil Nadu state of India. The present paper aims to investigate the land use changes over the time period, 2005 to 2014, in the Ousteri wetland using the information collected through the ecological, hydrological and GIS data. The quantitative research on Ousteri wetland land use/cover change could provide scientific basis for monitoring wetland environment change and sustained utilization of

wetland resource. The Ousteri wetland generates multiple benefits–such as, irrigation water, water for drinking, bathing and washing, supply of food, fibre, fodder and reeds, recreational benefits and so on that are utilised by a large number of economic agents. At the same time, the wetland experiences sever 'negative externalities' that include encroachment, non-point source pollution from agriculture and human settlements, industrial pollution, over-grazing, siltation, illegal fishing and poaching of wildlife, and various other human activities leading to 'tragedy of commons' problem in the wetland. If the present situation continues, deterioration in the ecosystem services would lead to adversely affect the inter-temporal welfare of the human beings. Having identified important ecosystem services and quantified them in physical units, economic valuation exercise would attempt to estimate the monetary value of these services.

Site Description

Ousteri Lake is popularly called Ousteri which is a word formed out of the fusion of Tamil words Oussudu (a proper noun) and eri (meaning a lake). Ousteri is an inter-state lake about 50 percent of its waterspread lies in Puducherry and the rest in Tamil Nadu (Figure 1). Ousteri Lake is situated near the village Oussudu, at 11° 56' 51" N, 79° 44' 13" E, partly in Puducherry and partly in Tamil Nadu (Figure 1). But whereas much of the Ousteri bank in its Tamil Nadu side consists of rural settlements, the Puducherry side of the lake is predominantly urban or suburban. This results in special stresses on the lake which have been dealt in subsequent chapters.

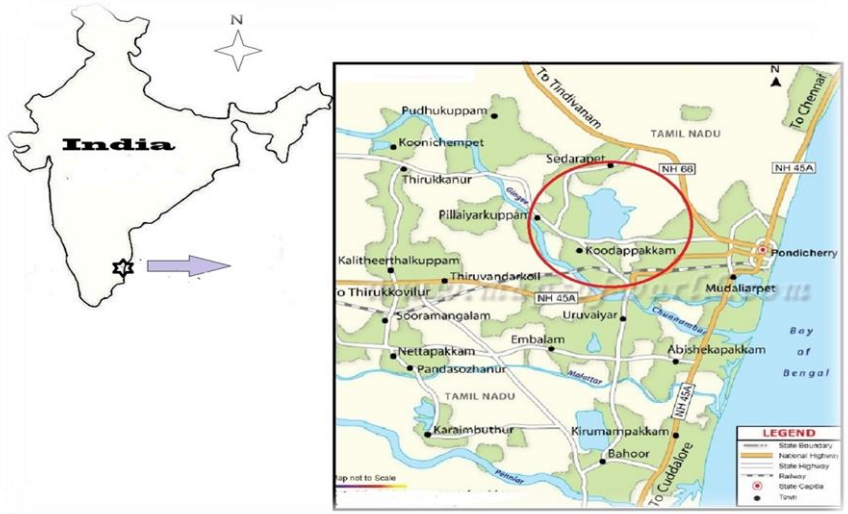

Figure 1: Location Map of the Ousteri Wetland

Ousteri is the largest fresh-water lake of Puducherry region, covering some 700 hectares when full after a normal monsoon. It can store 540 million cu. ft. of water, capable of irrigating close to 3800 hectares of land (Abbasi, 1997). But what distinguishes Ousteri the most is its ability to attract a very rich and diverse population of migratory birds, making it one of the most important wetlands of Asia. Ousteri lies about 16 km. Ousteri has been popular with perches as well as waders among the birds, thereby attracting larger number of avian species.

Ousteri plays a crucial role in recharging the groundwater aquifers. It also harbours rich flora and fauna; indeed it is such an important wintering ground for migratory birds that it has been ranked among the most important wetlands of Asia (Scout, 1989). In the recent past, Ousteri lake and its watershed have been subject to enormous pressures due to increasing population, industrialization and urbanization. Though there had been research works on proposing conservation management plans for the Ousteri Lake, but not much work had been

done to analyse the economic value of the lake and to estimate the value it could gain by conservative measures. With this aim in mind, the present project was conducted to analyse the economic valuation of the Ousteri lake. Prior to the economic aspect, almost all the aspects of the Ousteri lake was inferred through the geographic assessment and provide vital links between the geology, hydrology and ecological information.

Data and Land Use Classification

According to the research purpose and status of the study area, the land use classification system of Ousteri wetland region was divided into four types that Water body, Settlements, Vegetation / Agriculture and Scrub / Fallow. Based on the geo-referenced images in three dates, the images were interpreted by supervised classification. Then using GIS tool, the land use data of Ousteri wetland in the two years were extracted as the basic data of land use/cover change analysis.

Land Use Dynamic Degree Model

The land use change was determined using the land use dynamic degree model that included the single land use dynamic degree model and the synthesis land use dynamic degree model. Region differences in the rate of land use change were determined with the single land use dynamic degree that could be mathematically expressed by the following relationship (Li and He, 2002):

$$S_i = (A_i\text{-}UA_i)/A_i/(T_2\text{-}T_1)\times 100 \text{ percent} \quad (1)$$

Where S_i is the rate of the ith type land use change during the monitoring period T_1 to T_2; A_i is the area of the ith type land use at the beginning, and UA_i is the area of the ith type land use that remains unchanged during this monitoring. Thus, this model represented the time rate of change for one type of land use that was converted into another type of land use relative to the land use situation at the beginning of the

monitoring period. Regional difference in land use characteristics was determined using the synthesis land use dynamic degree model as follows (Liu and Buhe, 2000):

$$S = [\sum(\Delta A_{i-j}/ A_i)]\times(1/t) \times 100 \text{ percent} \quad (2)$$

S is the land use change rate over time t, A_i is the ith type land use area at the beginning of the monitoring period, and ΔA_{i-j} is the total area of the ith type land use that is converted into the other types of land use. This model was thus defined as the time rate change of land use that converted into the other types of land use and that at the beginning of monitoring period was part of the land use subject to change. This dynamic degree represented, in a comprehensive manner, the change of land use in a given region.

Quantity Analysis of Land Use Changes

The temporal land use changes for Ousteri wetland nature reserve locating in the study area were shown Figures 2 to 6. The data indicated that three land use types decreased while one increased from 2005 to 2014 (Table 1). Scrub / fallow land had an increase with the average annual variation of 49.69 ha/year. The decrease in the land use type of water body, vegetation/agricultural land and settlements in the Ousteri wetland nature reserve was observed to be at an average annual variation of 5.32 ha/year, 16.24 ha/year and 12.14 ha/year, respectively.

Table 1: Area of Different Land Use Types in Two Years and Land Use Changes from 2005 to 2014

Type Wetland	Area (ha) 2005	Area (ha) 2014	Annual Average Change (ha/year)
Water body	1196.72	1148.85	-5.32
Settlements	913.61	767.43	-16.24
Vegetation / Agriculture	2731.13	2621.88	-12.14
Scrub / Fallow	1863.36	2310.57	49.69

Source: Author Interpretation from the research work.

The land use change for the two periods displayed in the above table depicted a decrease of water body. The areas for vegetation /agricultural land and settlements decreased largely. During the two periods of observation, the scrub / fallow land conversion had increased and the ratio of the increase of the fallow land with that of the aggregate decrease of water body, agriculture and settlements was about 1:1. It was observed that the most of land use changes indicated that the utilization of land resources in Ousteri nature reserve tended to more and more of scrub land variety with time.

Land Use Dynamic Degree Analysis

Among the various land use types examined in the two periods, the annual conversion rate to scrub/fallow land was the highest. Conversion to the fallow land has occurred from the water body, settlement and vegetation /agriculture zone of the Ousteri wetland (Table 2). Though some area of the scrub/fallow area land use pattern has converted to the water body landscape, which is a positive sign of increase in water footprint; the overall increase of

Table 2: The Land Use Conversion Matrix from 2005 to 2014

Type Wetland	Water Body	Settlements	Vegetation / Agriculture	Scrub / Fallow
Water body	1053.11	0	0	143.61
Settlements	0	767.43	0	146.18
Vegetation / Agriculture	0	0	2512.64	218.49
Scrub / Fallow	95.74	0	109.25	1802.29

Source: Author Interpretation from the research work.

Water area of the wetland is not higher than the conversion of the landscape into the fallow land. This could be correlated to the high extraction of ground water and surface water of the wetland for the

utility of the neighbouring amusement parks and the medical institutes. On the other side of the wetland, few hectares of settlements and natural vegetation zone of the Ousteri wetland was observed to have converted to scrub /fallow land, which is a direct impact of the rapid increase in the anthropogenic activities noticed in the wetland. The effluent release by the industrial belt and conversion of agricultural land to real estate activity which is due course of time has possibility of accelerating into the building zone are contributing to the land use pattern conversion.

Most of the dry land changes involved converting to water body. However, the total dry land area increased because of conversions from irrigated land. Irrigated land mainly converted to dry land and forest and grass land, while forest and grass mainly converted to land irrigated land in the two periods.

The single land use dynamic degree for each land use types that is the annual conversion rates of land use types were calculated. Among the various land use types, the loss of wetland was mainly the conversion to fallow land. However, the total fallow land area increased because of conversions from the agricultural land.

In the meantime, the conversion from some fallow land led to the increase in the agricultural land and water body deposit. The decrease in the settlements zone was noticeable, which mainly converted scrub land (Table 3). The synthesis land use dynamic degree of Ousteri wetland nature reserve for the period 2005 to 2014 was 1.7 percent.

Table 3: The Land Use Dynamic Degree of Each Land Use Types for the Two Periods

Land use Dynamic Degree	Type	2005 to 2014 (Percent Change)
Single land use dynamic degree	Water body	1.33
	Settlements	1.78
	Vegetation /	0.89
	Agriculture	0.36
	Scrub / Fallow	
Synthesis land use dynamic degree		1.7

Source: Author Interpretation from the research work.

Driving Factors of Land Use Change

The driving factors of land use changes include two aspects of natural and artificial driving factors. For the natural factors, climate-driven change in the hydrological conditions is the key factor causing the changes of the wetland in the nature reserve. As we know, water is key element to maintain its spatial distribution and ecological function for the wetland (Yu *et. al.*, 2010). As the direct and important supply source, precipitation within the watershed is an essential factor for the wetland landscape change. During the warm and dry season of Puducherry region where the Ousteri wetland is located, the precipitation and runoff volume reduced and became unstable. This has caused the area of wetland to shrink, bring the conversion from wetland to terrestrial land use types. The socio-economics and policies are the major driving forces for land use/cover change, and human disturbances accelerate the changes of land use patterns in the wetland.

In this study for Ousteri wetland nature reserve, for the sake of pursuing economic benefit, dried wetland area has been transformed to real estate landscapes or as agricultural land. Hence, wetland loss in the Ousteri wetland nature reserve can not only be attributed to natural climate and precipitation conditions, but also to direct anthropogenic activities. Ultimately, as the result of natural factors and human

disturbances, the land use patterns has been changed, this may cause an adverse influence on wetland ecological environment and landscape quality.

CONCLUSION

The land use changes during the period 2005 to 2014 in Ousteri wetland were analyzed using the GIS tool. Firstly, temporal changes of land use characteristics were quantitatively analyzed through land use dynamic degree. And then the driving forces of land use changes were analyzed based on natural and artificial factors. From 2005 to 2014, as the result of natural factors and human disturbances, the area of wetland shrunk, bringing the conversion from wetland to terrestrial land use type. The annual conversion rates indicated the land use changes in Ousteri wetland. Through the synthesis land use dynamic degree, it could be inferred that the management of Ousteri wetland must focus on wetland land use changes in future, so as to achieve effective conservation of the wetland.

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