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Geospatial analysis of impact of changing land use pattern on paddy wetlands: a case study of Thrissur District, Kerala, India.

Análisis geoespacial del impacto del cambio en el patrón de uso de la tierra en los humedales de arrozales: un estudio de caso del distrito de Thrissur, Kerala, India

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ABSTRACT

Paddy wetlands of Kerala are a victim of incongruous land use pattern and a major portion of paddy lands in the state has already been converted to other purposes. This study employs geospatial technology to analyse the conversion of paddy wetlands to other land uses and also compares the reclamation of paddy fields before and after the enactment of the Kerala Conservation of Paddy Land and Wetland Act in 2008. The study area is Thrissur district, Kerala, India and the period of study is from 1995 to 2021. The results of the analysis revealed that a significant percentage (4.28%) of paddy wetlands got reclaimed during the period 1995-2008. Conversion to mixed crops, built-up and wasteland was 10,098.41 hectares, 2,151.38 hectares 747.37 hectares respectively. After 2008 there is a marked reduction in the reclamation, but pollution and degradation of the wetlands still continues. This encroachment and deterioration of paddy lands have impacted the rice production of the study area.

Key words: Remote sensing, Rice cultivation, Land cover, Wetlands, Reclamation

RESUMEN

Los humedales de arroz de Kerala son víctimas de patrones incongruentes de uso de la tierra y una gran parte de las tierras de arroz del estado ya se han convertido para otros fines. Este estudio emplea tecnología geoespacial para analizar la conversión de los humedales de arroz a otros usos de la tierra y también compara la recuperación de los arrozales antes y después de la promulgación de la Ley de Conservación de Tierras de Arroz y Humedales de Kerala en 2008. El área de estudio es el distrito de Thrissur, Kerala , India y el período de estudio es de 1995 a 2021. Los resultados del análisis revelaron que un porcentaje significativo (4,28%) de los humedales de arroz fueron recuperados durante el período 1995-2008. La conversión a cultivos mixtos, urbanizados y baldíos fue

de 10.098,41 hectáreas, 2.151,38 hectáreas y 747,37 hectáreas respectivamente. Después de 2008 hay una marcada reducción en la recuperación, pero la contaminación y degradación de los humedales aún continúa. Esta invasión y deterioro de los arrozales ha impactado la producción de arroz en el área de estudio.

Palabras clave: Teledetección, Cultivo de arroz, Cobertura terrestre, Humedales, Recuperación

INTRODUCTION

Ever since the arrival of humans on earth, wetlands have endowed man with numerous ecological and economic services such as provision of food and water, purification of water, flood mitigation, harboring biodiversity, storm resilience, shoreline stabilization, carbon sequestration and recreational benefits. Ironically, with the development of human race, man took wetlands for granted and started encroaching and destroying them. The ecological services accrued from wetlands are not attached monetary value, hence they are traded off in exchange for monetary benefits from developmental activities.

The Ramsar Convention (1971) defines wetlands as “areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters”.

Due to the diverse nature of wetlands, classification of wetlands has been a daunting task and every region has its own classification. Worldwide, numerous classifications of wetlands have been put forth (Martin 1953, Ramsar Convention 1971, Stewart and Kantrud 1971, Cowardin et al.1979, Schempf 1992).

In India, under the instruction of Ministry of Environment and Forests, Space Applications Center classified and mapped the wetlands of India at 1:250,000 scale in 1992-93 and 2004-05 using IRS 1A LISS-I/II data and IRS P6/ Resourcesat AWIFS data respectively. In 2010 as part of a national-level project named National Wetland Inventory and Assessment, Space Applications Center and Kerala State Remote Sensing and Environment Center mapped the wetlands of Kerala at a scale of 1:50,000 using IRS-P6- LISS III data. But these classifications and mapping did not include paddy wetlands. However paddy wetlands are an integral part of the geography of Kerala and forms the largest category of wetlands in the state. A paddy wetland is a piece of flooded lowland used for cultivation of many varieties of rice of which Pokkali rice has attained Geographical Indication tag. They are sometimes used for integrated rice-shrimp farming also.

Understanding the unique and diverse nature of wetlands of Kerala, Kerala State Remote Sensing & Environment Centre Planning (KSREC) prepared an inventory of wetlands of Kerala on a scale of 1:10,000 using Cartosat-2 data. This inventory includes paddy wetlands.

Though paddy wetlands are vital they have been the prime victim of population pressure, urbanization and the rapidly changing land use pattern in Kerala and the state has already lost a major portion of her wetlands. This study aims to provide a picture of the conversion of paddy wetlands of Kerala by considering Thrissur district as a case study.

Thrissur district was chosen because it is situated in the central part of Kerala and encompasses all three physiographic division of Kerala – Lowlands, Midlands and Highlands. As per census of India reports of 2011 the district has a high population density of 1,026 persons per square kilometer which is greater than the state population density of 860 persons per square kilometer. At the same time, the study area is witnessing rapid urbanization. According to census reports (2011), out of the total 520 towns in the Kerala, Thrissur district with 135 towns stood first, followed by Kannur district (67 towns) and Ernakulum district (56 towns). The percentage of urban population in Thrissur district increased from 28.22% (2001) to 67.19% (2011) making her leap from sixth rank to second rank. The district is also home to a unique wetland system named Kole wetlands, which is a part of the Ramsar site- the Vembanad –Kole wetlands. Apart from providing bumper yields of rice, the Kole wetlands form a natural drainage for flood water. The paddy wetlands of Thrissur have faced the brunt of high population density, rapid urbanization, clay mining and the resultant land use land cover changes.

The Kerala Conservation of Paddy Land and Wetland Act was passed in 2008 with the aim of conserving wetlands and putting a stop to the encroachment of wetlands. This study compares the paddy wetland conversions that took place during a 13 year period (1995-2008) prior to the enactment of the Act and the conversions that happened during a 13 year period (2008-2021) post the enactment of the Act, thus evaluating the effectiveness of the Act in conserving paddy wetlands of the state.

MATERIALS AND METHODS

Study Area: The study area (Figure 1) bears the coordinates of 10° 10’ and 10° 46’ North latitudes and 75° 57’and 76° 54’ East longitudes and is geographically located in the central part of Kerala state, India. The 3032 km² area slides from the Western Ghats in the east to the Arabian Sea in the west. Thrissur district accounts for 7.8% of the total area of Kerala. The district is surrounded by Malappuram and Palakkad districts in the north, Idukki and Ernakulam districts in the south, Palakkad district and Coimbatore district of Tamil Nadu in the east and Arabian Sea in the west. Topographically the district can be divided into 5 divisions i.e. the Lowland region (elevation of 20m above Mean Sea Level), the Midland region (20m to 100m), the Mid-uplands (100m to 300m), the Uplands (300m to 600m) and the Highlands (above 600m.) The general climate is tropical humid climate.

Methodology: The primary data for this study constitutes satellite imageries of the years 2021, 2008 and 1995 downloaded from US Geological Survey website (https://earthexplorer.usgs.gov). Landsat 8 OLI_TIRS was downloaded for the year 2021 and Landsat 5 TM for the years 2008 and 1995. The imageries were of path 144 and

row 53 and had a spatial resolution of 30 meters. Necessary radiometric and geometric corrections were performed on the images.

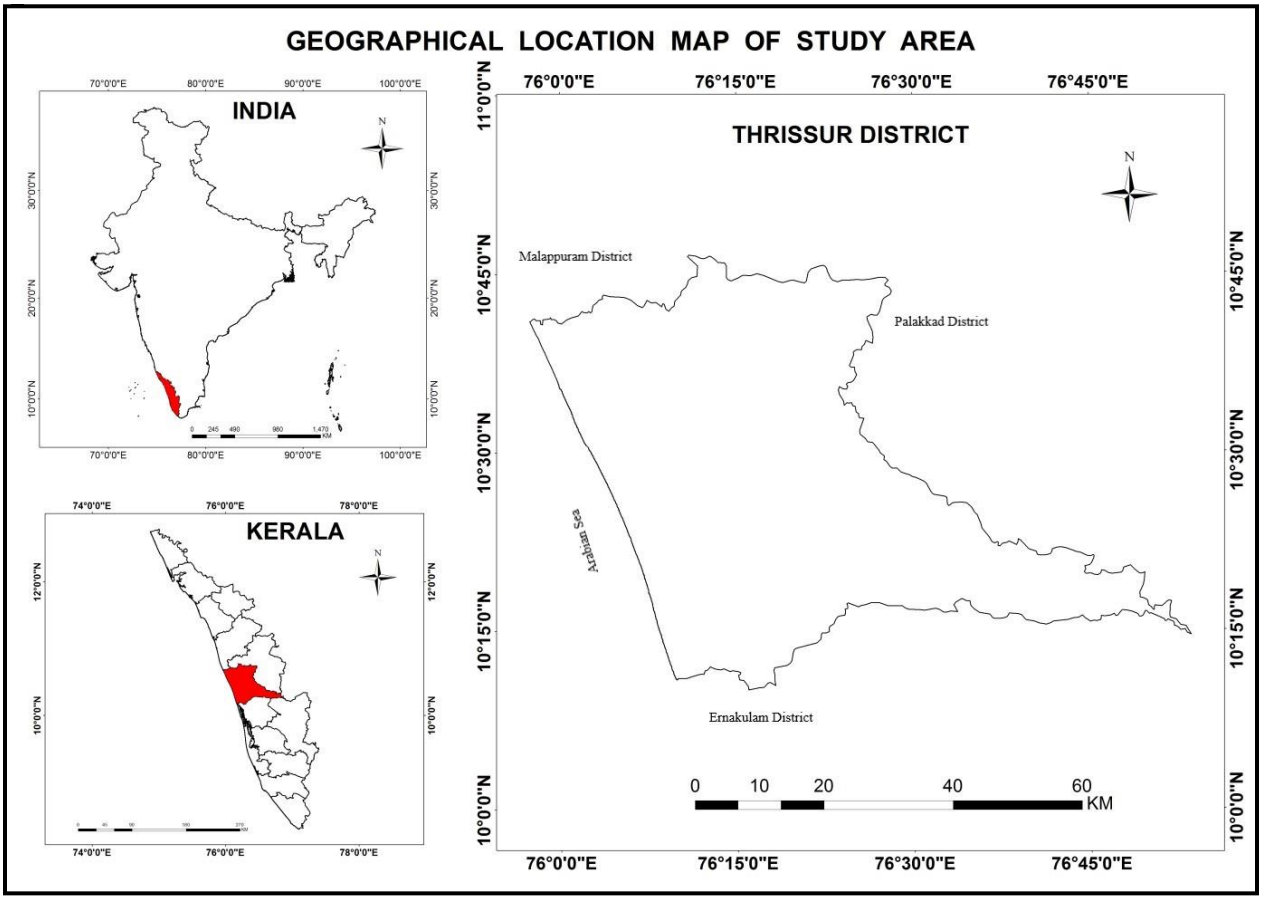

Figure 1. Thrissur District: Geographical Location Map

Land use land cover maps were prepared for the years 1995, 2008 and 2021 by performing supervised classification using Maximum Likelihood Classification algorithm. 7 land use land cover classes were identified- built-up, forest, mixed crops, paddy wetlands, scrub and barren land, wasteland and wetlands other than paddy wetland. 'Built-up' land includes all manmade structures such as houses, commercial buildings, roads, bridges, industrial establishments etc. Reserved forests, open forests and plantations of different species found in highland areas have been included in the category of 'Forests'. 'Mixed crops' comprises of homestead crops and plantation crops like coconut, arecanut, plantain, banana, nutmeg grown on a commercial scale in the lowlands and midlands. Wetlands used mainly for paddy cultivation comes under the category of 'Paddy wetlands' while all other wetlands like rivers, streams, estuaries, backwaters, canals, mangroves, ponds and lakes come under the category 'Wetlands other than paddy wetland'. Abandoned clay mining sites and quarrying sites come under 'Wastelands'. 'Scrub and barren land' includes rocks with scrub vegetation and land not used for any notable activity. The supervised classified images had

some classification errors, for instance some pixels that were actually harvested paddy fields were erroneously classified into built-up and some trees that belonged to the mixed crop category were confused as forest. Therefore manual editing of pixels was performed to assign the wrongly classified pixels to the correct land use class.

Thereafter accuracy of the classified images was checked in ERDAS Imagine software with the help of ground truth points collected during field survey, Survey of India toposheets and Google Earth Pro. The 1995, 2008 and 2021 classified images yielded overall accuracy of 86%, 89% and 93% respectively. Then the area under each land use category and the change in area was quantified. The paddy wetland was extracted from the final land use land cover maps and nature and magnitude of conversion of paddy lands to other land uses was mapped and calculated. The software used for the whole process were ArcGIS 10.8, Erdas Imagine 14 and Microsoft Excel.

Ancillary data used for this study includes the Survey of India toposheets of 1966 at 1: 50,000 scale, Agricultural Statistics reports published by Economics and Statistics Department of Government of Kerala, District Census Handbook of Thrissur District published by Government of India and Inventory of Natural wetlands of Kerala published by Kerala State Remote Sensing & Environment Centre Planning

Face to face interview with farmers was also conducted to understand the threats to paddy cultivation.

RESULTS AND DISCUSSION

Conversion of Paddy Wetlands to Other Land Uses: Analysis of land use land cover maps of Thrissur district for the years 1995, 2008 and 2021 (table 1, table 2 and table 3) and (figures 2, figure 3 and figure 4) reveals that from 1995 to 2008 a sizeable portion of paddy wetlands got converted to mixed crops , built-up and wasteland. During the period 1995-2008, 10,098.41 hectares of paddy wetlands got converted to mixed crops including coconut, nutmeg, arecanut, rubber, tea and other homestead crops. Increased cost of cultivation, scarcity of labour, high labour costs, non-profitability etc caused this shift in cultivation from subsistence crops like rice and tapioca to more remunerative cash crops like coconut, rubber, tea, cocoa, spices and condiments etc. During the same period 2,151.38 hectares of paddy wetlands got converted to built-up including roads, palatial residential houses, multi-storey apartments and commercial buildings. The break-up of joint family system coupled with remittances from abroad led to the increase in the number of residential built-up both in urban and rural areas. Shelter is often not viewed as one of the basic necessities of life, but as a symbol of prestige and social status. As such building enormous houses devouring huge parcels of land has become a norm. Paddy fields were the prime target of the real estate sector as being lowlands they could be purchased at lower prices for construction activities. The proximity to Kochi city also aided this process. At the same time 747.37 hectares of paddy wetland was converted to wasteland due to clay mining. The presence of good quality clay suitable for production of clay bricks and tiles in the paddy fields of Thrissur tempts the paddy cultivators to lease out the land for clay mining which seems to be more profitable than paddy cultivation. Suraj and Neelakantan (2014) found 124 clay mining affected locations in Thrissur district. Clay

mining causes the land to become unproductive as all nutrients are removed. Steps must be undertaken by the Government to stop indiscriminate mining of clay from paddy fields.

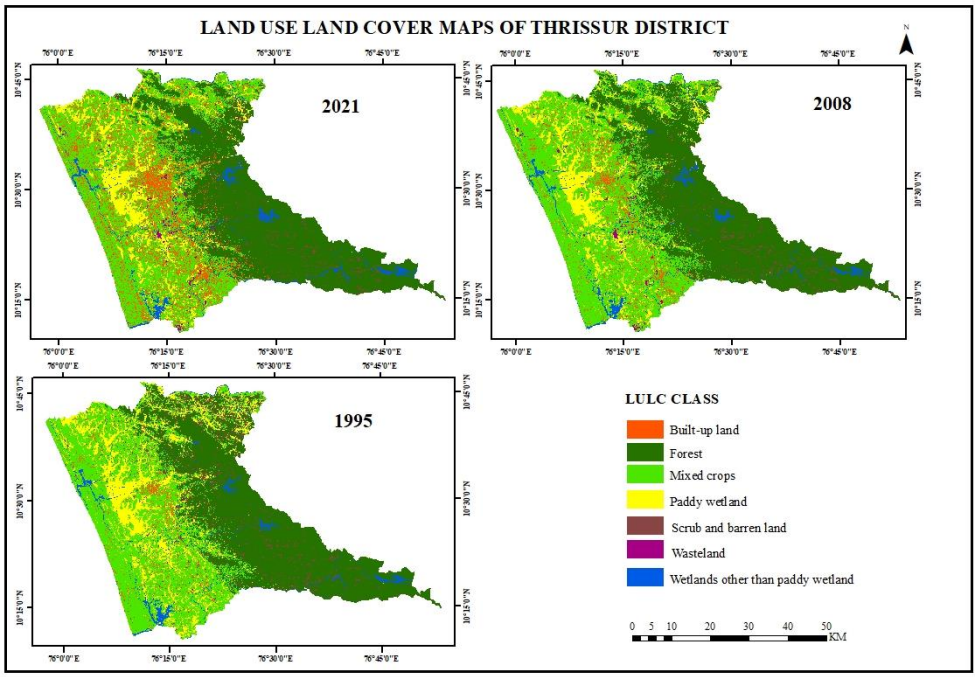

Figure 2. Thrissur District: Land use Land Cover Maps of 1995, 2008 and 2021

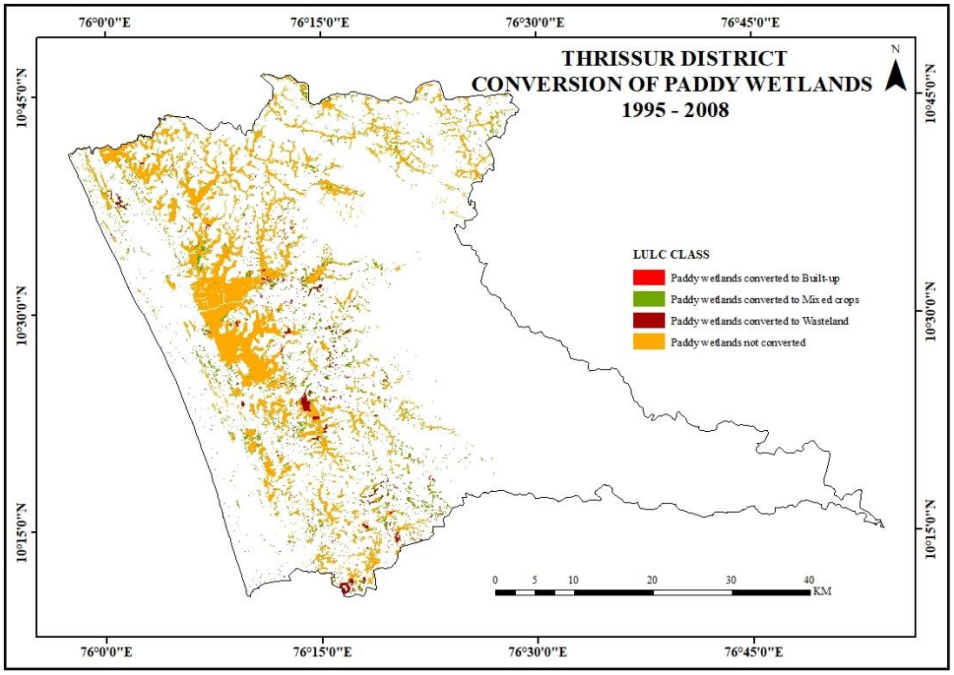

Figure 3. Thrissur District: Conversion of Paddy Wetlands to other Land use, 1995-2008

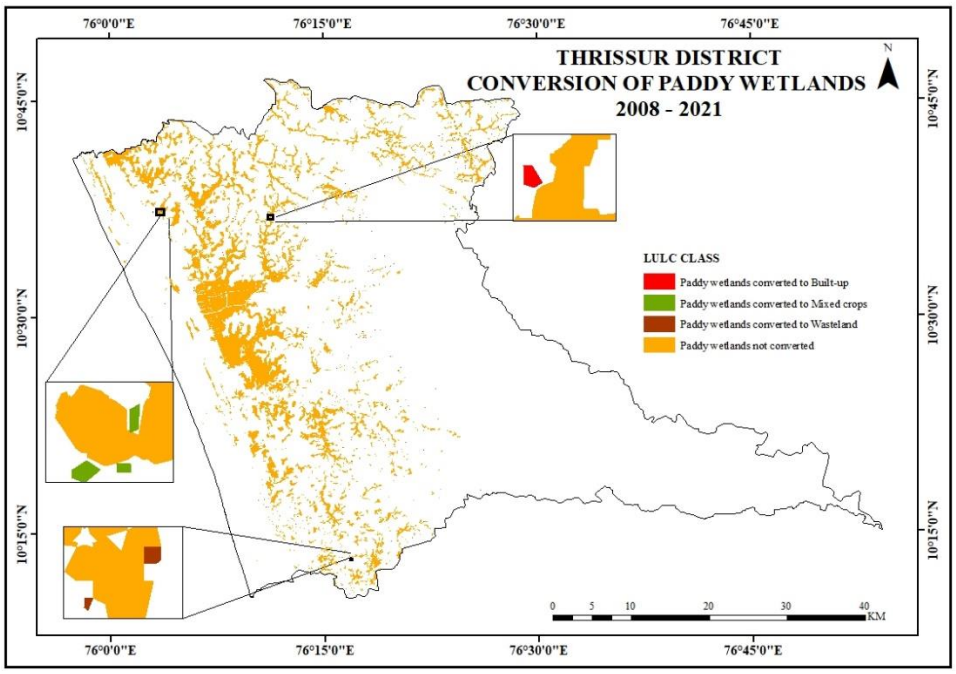

Figure 4. Thrissur District: Conversion of Paddy Wetlands to Other Land use, 2008-2021

Table 1. Thrissur District: Land Use Land Cover in 1995, 2008 and 2021

LULC Class	1995		2008		2021	
	Area (Ha)	Area (%)	Area (Ha)	Area (%)	Area (Ha)	Area (%)
Built up Land	9474.03	3.12	16428.32	5.41	31627.29	10.43
Forest	105714.35	34.86	101223.27	33.38	93367.05	30.79
Mixed crops	117423.82	38.72	130616.70	43.07	124945.86	41.20
Paddy Wetlands	45686.08	15.06	32688.92	10.78	32431.62	10.69
Scrub and Barren	4912.52	1.62	4225.06	1.39	2976.31	0.98
Wasteland	4726.96	1.55	6296.73	2.07	6686.87	2.20
Wetlands other than paddy wetland	15262.24	5.03	11721.00	3.86	11165.00	3.68
Total	303200.00	100	303200.00	100	303200.00	100

Source: Computed by authors from Landsat Imagery

Table 2. Thrissur District: Area and Percentage of Change in Land Use Land Cover -1995 to 2021

LULC Class	1995- 2008		2008-2021	
	Area (Ha)	% Change	Area (Ha)	% Change
Built up Land	+ 6954.29	+ 73.40	+ 15198.97	+ 92.51
Forest	- 4491.08	- 4.24	- 7856.22	- 7.76
Mixed crops	+ 13192.88	+ 11.23	- 5670.84	- 4.34
Paddy Wetland	- 12997.16	- 28.44	- 257.30	- 0.78
Scrub and Barren	- 687.46	- 13.99	- 1248.75	- 29.55
Wasteland	+ 1569.77	+ 33.20	+ 390.14	+ 6.19
Wetlands other than paddy wetland	- 3541.24	- 23.20	- 556.00	- 4.74

Source: Computed by authors from Landsat Imagery

Table 3. Thrissur District: Conversion of Paddy wetlands to Other Land Uses - 1995 to 2021

Period	To Mixed crops (Ha)	To Built-up (Ha)	To Wasteland (Ha)	No conversion (Ha)
1995-2008	10098.41	2151.38	747.37	32688.92
2008-2021	154.18	82.00	21.14	32431.62

Source: Computed by authors from Landsat Imagery

The Kerala Conservation of Paddy Land and Wetland Act was passed in 2008 aiming to regulate the conversion of the wetlands of the state. Apart from augmenting agricultural growth, the Act recognized the fact that wetlands are crucial for sustaining the integrity of the state. Results of this study clearly indicates that the Kerala Conservation of Paddy Land and Wetland Act (2008) was successful in bringing down the reckless reclamation of paddy land. During the period 2008-2021 conversion of paddy wetlands to mixed crops, built-up and wasteland were 154.18 hectares, 82.00 hectares and 21.14 hectares respectively. Though the areal extent of the fields have not reduced much since 2008, pollution of these wetlands still continues.

However the Kerala Conservation of Paddy Land and Wetland Act was amended in 2018. Environmentalists and other stakeholders fear that this amendment will dilute the restrictions put in place by the original Act and place the wetlands in danger.

Buffer Analysis: Conversion of Paddy Wetlands from Thrissur City: Thrissur city is the administrative headquarters of the Thrissur district and is the main commercial hub of the district. Proximity to the city center will directly influence land use pattern of the surrounding area. So a buffer analysis was done to find out the trend of conversion of paddy wetlands as we move away from the city center. (table 4 and figure 5). During the period 1995-2008 conversion of paddy lands to built-up showed a decreasing trend with distance from the city center. Encroachment for built-up was maximum in the 0-5 km buffer zone (212.41 hectares). Paddy fields were reclaimed mainly for the construction of commercial establishments, educational institutions, hospitals, residential apartments etc. Conversion to built-up ultimately reduced to 192.36 hectares in the 10-15 km buffer zone where the conversion was dominated by residential houses. However it should be kept in mind that largescale encroachment of paddy fields in proximity to Thrissur city had already happened prior to 1995. During the same period conversion of paddy wetlands to mixed crops and wastelands showed an increasing trend with distance from the city center. Due to the exorbitant price of land in the city, reclamation for agriculture is less profitable than reclamation for construction activities. Conversion to mixed crops was 517.90 hectares in the 0-5 km buffer zone, 950.81 hectares in the 5-10 km buffer zone and 1,617.57 hectares in the 10-15 km buffer zone. Conversion of paddy fields to wasteland which was dictated by presence of good quality clay was to the tune of 61.02 hectares, 131.29 hectares and 255.4 hectares in 0-5 km, 5-10 km and 10-15 km buffer zones respectively.

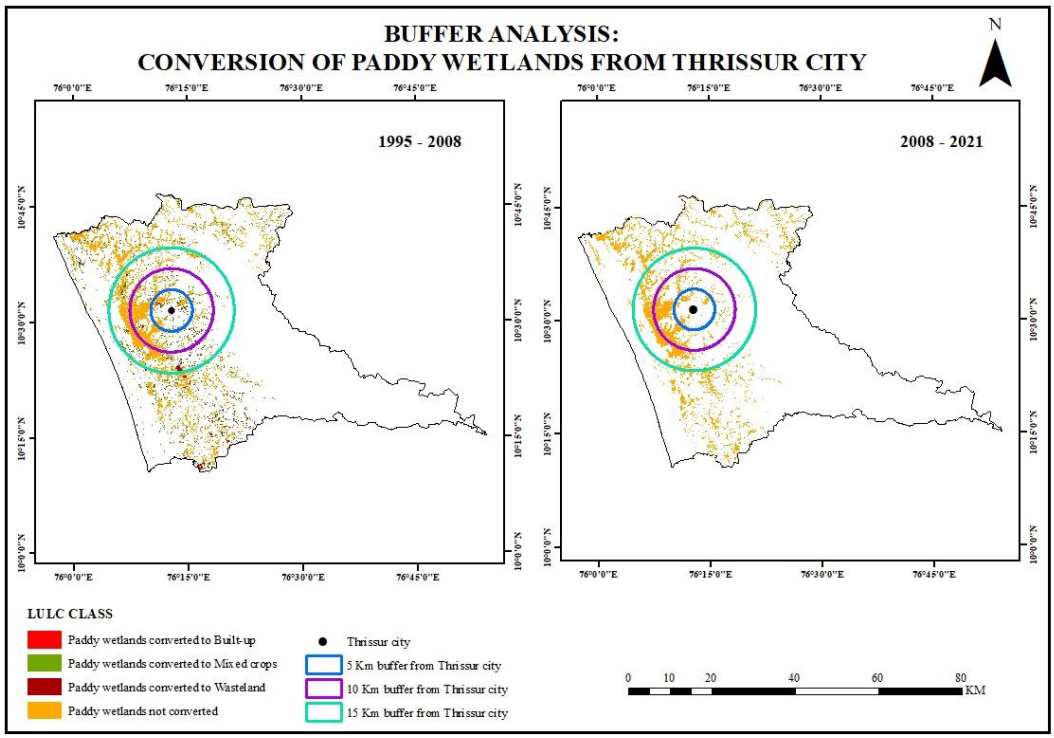

Figure 5. Buffer Analysis: Conversion of Paddy Wetlands from Thrissur City, 1995-2021

Table 4. Thrissur District: Buffer analysis of Conversion of Paddy wetlands from Thrissur City - 1995 to 2021

	1995 - 2008			2008 - 2021		
Buffer	To Mixed crops (Ha)	To Built-up (Ha)	To Wasteland (Ha)	To Mixed crops (Ha)	To Built-up (Ha)	To Wasteland (Ha)
0-5 km	517.90	212.41	61.02	5.29	0.62	2.96
5-10 km	950.81	195.31	131.29	16.61	1.43	5.27
10-15 km	1617.57	192.36	255.40	8.16	0.98	6.04

Source: Computed by authors from Landsat Imagery

Table 5. Thrissur District: Production of Rice -1995-96 to 2020-21

Year	Production(Tonnes)	Change(tonnes)
1995-96	110698	
2008-09	71909	-38789
2020-21	87655	+15746

Source: Agricultural statistics, Directorate of Economics and Statistics, Government of Kerala

During the period 2008 to 2021, the only significant conversion was paddy lands to mixed crops which was 5.29 hectares, 16.61 hectares and 8.16 hectares in 0-5 km, 5-10 km and 10-15 km zones respectively. The buffer analysis revealed only minor conversions to built-up and wasteland after the enactment of the Kerala Conservation of Paddy Land and Wetland Act in 2008.

Impact of paddy wetland conversion on paddy cultivation: Rice is the most important staple food of the people of Kerala. In every agricultural year, paddy is cultivated in the wetlands of the state during three seasons. Autumn season traditionally known as Virippu is from July 1st to 31st October. The winter season or Mundakan is from 1st November to 28th February and summer season or Puncha is from 1st March to 30th June.

However large-scale conversion of paddy wetlands for non-agricultural purposes and for the cultivation of cash crops and homestead crops has resulted in a concomitant decline in production of rice as seen in table 5. It is evident that the total production of rice in Thrissur district plummeted from 1, 10,698 tonnes in 1995-96 to 71,909 tonnes in 2020-21, thereby resulting in a reduction of 38,789 tonnes. But a reassuring fact is that from 2008-09 to 2020-21, the production of rice has increased by 15,746 tonnes. The reasons for this increase in paddy production include enactment of the Kerala Conservation of Paddy Land and Wetland Act, provision of free water pump motor and free electricity for paddy cultivation, subsidies given for seeds and fertilizers. Also organization of farmers into collective farming groups locally known as Padashekharam facilitated sharing of farm machinery and other resources.

Other threats to paddy cultivation and suggestions for mitigation: Face to face interviews with farmers and officers of the collective farming groups (locally known as Padashekharam) were conducted to get an insight into the problems they faced in cultivation of paddy and to seek their opinions for tackling these problems. The following are some of the problems they pointed out:

The steady rise in cost of cultivation is a major obstacle to paddy cultivation. The Government provides free water pump motors and free electricity for cultivation and subsidies for seeds and fertilizers. According to the cultivators who were interviewed, the gap between the cost of cultivation and the subsidies received is very huge resulting in reduced profits. So productivity must be increased and the cost of cultivation must be brought down. Some farmers even suggested using organic manure to bring down the use of expensive fertilizers.

A major component of the cost of cultivation is the labour cost which amounts to approximately Rs 500 to Rs 600 per day for local labourers. The ever increasing wage rate of local labourers for every agricultural activity has resulted in the employment of migrant labourers in the paddy fields because they charge a lower wage. But employing migrant workers does not ensure continuity in work as they might not be available for work on a regular basis. So the farmers pleaded for mechanization. If the Government provides machinery, labour costs can be reduced.

The cultivators also complained about delayed disbursement of subsidies. Cultivators have to approach many Government offices to get their official works such as approval for subsidies, approval for irrigation and farming machinery etc done. This is time and energy consuming. So the cultivators suggested that a single Government office to take care of the needs of paddy cultivators would be ideal.

Pollution and waste disposal is another threat. Discards from slaughter houses and storm water carrying municipal and domestic waste ultimately find their way into the wetlands. Pollution forced farmers of Kole paddy fields located near the city to abandon cultivation as they suffer from skin problems. (Jenin and Bhaskara 2017). Solutions to the problem of pollution can include improvement in the waste management system of the state, periodic cleaning of clogged canals, inculcating responsible behavior among citizens and tourists so that they don't throw plastic bottles, covers and other wastes into wetlands.

Weed and pest infestations and diseases also discourage cultivators. Moreover the present younger generation is no more interested in farming. With the exception of a few youngsters, the upcoming generation is attracted to white collar jobs in the country itself or prefer to migrate to other countries.

CONCLUSION

The paddy wetlands of Thrissur district were subjected to progressive encroachment and land filling and as a result a large portion of paddy lands have already been reclaimed to mixed vegetation, built-up and wasteland. The fact that their reclamation have been arrested to a great extent by the Kerala Conservation of Paddy Land and Wetland Act is commendable. But pollution and deterioration of the wetlands still continues. Efforts should be taken by the people as well as the concerned authorities to conserve the remaining paddy wetlands and to revamp paddy cultivation. Measures should also be taken to create awareness among the masses regarding the ecological services provided by wetlands in addition to the economic benefits from paddy cultivation and shrimp farming. Moreover, how the amendment to the original Act will affect wetlands remains to be seen. It is hoped that the Act will continue to protect the wetlands of Kerala as their destruction is bound to threaten food security in addition to increasing the occurrence of floods, reducing ground water recharge, depleting aesthetic value and harming biodiversity.

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