Assessing the Impact of Land Use Change on Stream Water Quality: A Comparative Analysis of Forests and Rubber Plantations in Kerala's Western Ghats

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Abstract
This study investigates the impact of land use composition on water quality in forested and rubber-planted watersheds in Kerala's Western Ghats region, India. The study aims to estimate specific water quality changes resulting from forest loss or gain and evaluate land use importance in the entire catchment compared to the riparian zone. Two micro-watersheds in the Karuvannur river basin were studied, with water samples collected from streams in reserve forests and rubber plantations.

Results indicate that streams in reserve forests exhibit higher dissolved oxygen levels, lower turbidity and lower total coliform bacteria compared to streams in rubber plantations. These findings highlight the potential adverse impacts of rubber cultivation on water quality and underscore the need for sustainable land and water management practices. The research offers valuable insights for environmental planning, conservation efforts and policy development to safeguard water sources in the Western Ghats region and similar ecosystems.

Keywords: Water quality, Reserve forest, Rubber plantation, Comparative study, Western Ghats land use impact, Stream ecosystem.

Introduction

The Western Ghats, a region recognized for its rich biodiversity in peninsular India, is experiencing increasing threats to its tropical forests, primarily due to logging and clearing for agricultural practices [16]. This shift in land use not only jeopardizes the existence of these forests but also threatens the critical ecosystem services they offer, including soil conservation and water protection. Commercial agriculture is identified as the leading cause of deforestation in developing nations, with subsistence agriculture as a close second[5]. The conversion of forested lands into agricultural spaces has been associated with deteriorating water quality, which can be attributed to various factors such as soil erosion from croplands, excessive usage of fertilizers, elevated animal stocking densities, construction activities and wastewater generation[4,10]. Contrarily, natural forests are instrumental in maintaining the high-water quality within watersheds[3,8,15]. Agricultural watersheds that contain forested areas demonstrate control over biogeochemical cycles, prevention of erosion, reduction in pollutant load, decreased nutrient runoff and lower water temperatures[9,12-14].

However, in numerous regions, including the Western Ghats, the current forest conditions represent a mosaic of disturbed forests, secondary vegetation and patches cleared for agriculture or other non-forest uses[1,4]. As the literature suggests there is a lack of understanding about the impact of changes in forest cover (density, age etc.) on stream water quality and there is a scarcity of studies quantifying specific water quality changes resulting from forest loss or gain[3]. This lack of knowledge hinders the inclusion of forest-related considerations in decision-making processes, such as cost-benefit analyses. The debate continues over the relative importance of land use within the entire catchment versus the riparian zone in influencing water quality[2]. Unique characteristics of each catchment influencing water quality make it challenging to apply research findings universally across countries, regions, catchment scales, forest types, species and management regimes[6].

To address these gaps, this research intends to study the effect of diverse land use on stream water quality in the Western Ghats of India. The focus will be on contrasting water quality impacts between forest streams flowing through natural forests and those flowing through converted rubber plantations. Gaining insights into the impacts of deforestation on stream water quality in this region is crucial to guide environmental planning, to inform conservation and restoration actions and to develop effective policies for water source protection.

Study area

This study focuses on two micro-watersheds located within the Western Ghats Mountain ranges in the Manali sub-basin of the Karuvannur river basin. The micro-watersheds studied are Pananchery (Fig. 1) and Poovanchira (Fig. 2). These areas are situated between 10° 15' to 10° 40' north latitude and 76° 00' to 76° 35' east longitude, spanning Thrissur and the Western boundary of Palakkad districts in the State of Kerala, India. The Karuvannur River basin, encompassing an area of 1054 km^2 is located in the Southern Western Ghats. This river basin comprises of 32 panchayats, 9 blocks and 2 districts. It is nourished by two major tributaries, namely the Manali and the Kurumali, originating from the Western Ghats.

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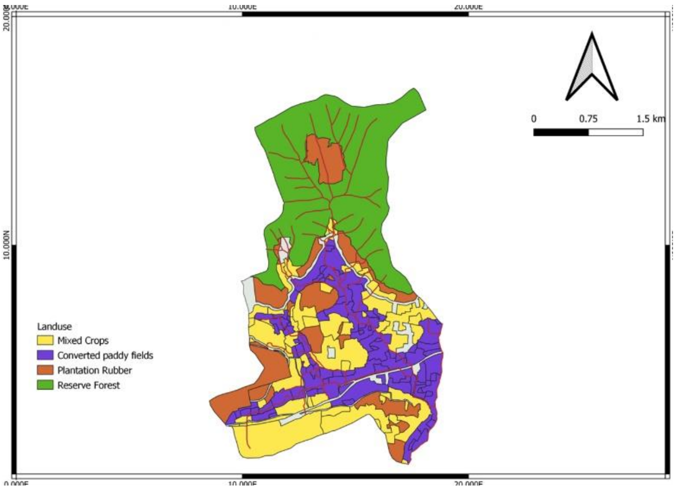

Fig. 1: Pananchery catchment: Landuse Landcover (2022)

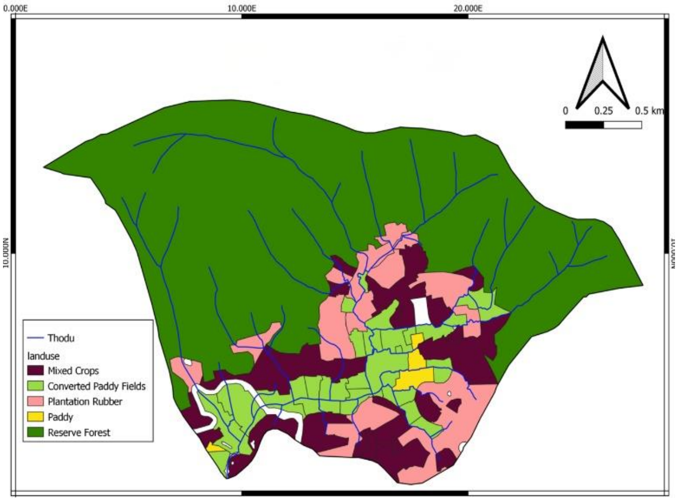

Fig. 2: Poovanchira catchment: Landuse Landcover (2022)

The study area experiences a characteristic rainfall pattern. Approximately 60 percent of the annual rainfall is received during the southwest monsoon, while 30 percent occurs during the northeast monsoon and the remaining 10 percent falls in the pre-monsoon season. The southwest and northeast monsoons are the primary sources of atmospheric precipitation in the region. The southwest monsoon, occurring from June to September, contributes the majority of the annual rainfall. The average annual rainfall ranges from 2500 to 3000 mm.

By studying the micro-watersheds within the Karuvannur river basin, this study aims to gain insights into the impact of land use change on stream water quality in the Western Ghats region. The specific focus will be on understanding the differences in water quality between forested areas and those converted for rubber plantation in this study area. In Pananchery, the reserve forest covers a substantial area of 335.731 hectares, which accounts for approximately 34 percent of the total area. This indicates a significant presence of forested land in Pananchery.

On the other hand, Poovanchira boasts a larger reserve forest area of 366.270 hectares, representing a significant portion of the total area at 66 percent. This suggests that Poovanchira is characterized by a more extensive and dominant reserve forest compared to Pananchery.

Comparing the area under rubber plantation, Pananchery has an area of 150.108 hectares dedicated to rubber cultivation, making up around 15.19 percent of the total area. In contrast, Poovanchira has a relatively smaller rubber plantation area of 62.285 hectares, constituting approximately 11 percent of the total area. These figures indicate that rubber cultivation is more extensive in Pananchery than in Poovanchira.

Material and Methods

The primary objective of this research was to conduct a comparative analysis of water quality parameters between streams flowing through a reserve forest (RF) and streams flowing through a rubber plantation (RPL) in the Western Ghats region of Kerala, India. The study period extended from July 2022 to December 2022, encompassing both the monsoon and post-monsoon seasons, to capture potential variations in water quality influenced by seasonal changes. To ensure robust and reliable data collection, water samples were collected from fixed sampling points established strategically within both the reserve forest and rubber plantation streams. The selection of these sampling points was carefully executed to representatively capture the overall water quality characteristics at each site. By consistently collecting water samples from the same predetermined locations throughout the study period, data comparability and reliability were ensured, reducing the potential for confounding factors in the analysis.

Sampling was conducted twice a month, resulting in a total of 12 observations for each site over the study duration. This approach aimed to capture both the monsoon season (July to September) and the post-monsoon season (October to December) to assess potential seasonal influences on the water quality parameters. The monsoon season, characterized by heavy rainfall and increased runoff, can have significant impacts on water quality due to soil erosion and nutrient leaching. The post-monsoon season, with reduced rainfall, allows for the evaluation of water quality during more stable flow conditions.

Laboratory analysis was carried out to measure various water quality parameters including dissolved oxygen (DO), pH, turbidity, nitrate levels, electrical conductivity (EC) and total coliform bacteria. These parameters are crucial indicators of water quality and can provide valuable insights into the ecological health of the streams. Statistical analysis was employed to compare the water quality parameters between streams in reserve forests and rubber plantations. The mean values of each parameter in RF and RPL were calculated and the significance of the differences was assessed using appropriate statistical tests. A p-value threshold of 0.05 was used to determine the statistical significance of the observed differences.

Ethical considerations were also taken into account during the research process. All sampling and data collection procedures were conducted following ethical guidelines and environmental regulations to minimize any potential negative impacts on the study area's natural ecosystem. Overall, this methodology aimed at providing a comprehensive and rigorous analysis of water quality parameters in streams within reserve forests and rubber plantations. The carefully designed sampling approach, covering distinct seasonal periods and the use of appropriate statistical analysis ensured the validity and reliability of the research findings. The results of this study contribute to a deeper understanding of the impacts of land use on water quality in the Western Ghats region, informing effective environmental planning and sustainable land and water management practices.

Results

Dissolved Oxygen (DO): The mean dissolved oxygen (DO) concentration in streams flowing through reserve forests (RF) was found to be significantly higher than in streams flowing through rubber plantations (RPL) in both Pananchery and Poovanchira sites. In Pananchery, the mean DO concentration in RF was 5.87 mg/L, while in RPL, it was 4.41 mg/L, with a p-value of <0.001. Similarly, in Poovanchira, RF had a slightly higher mean DO of 5.34 mg/L compared to RPL with 4.66 mg/L, but the difference was not statistically significant (p-value = 0.090). These findings suggest that reserve forests contribute to better water quality by maintaining higher levels of dissolved oxygen compared to rubber plantations. (Fig. 3).

pH: The mean pH values in streams flowing through reserve forests and rubber plantations exhibited some variations between the two study sites. In Pananchery, the mean pH in RF was 6.58, which was significantly lower than the mean pH in RPL at 7.07, with a p-value of 0.030. Conversely, in Poovanchira, RF had a slightly higher mean pH of 6.69 compared to RPL with 6.58, but the difference was not statistically significant (Table 1). These findings suggest that land use, particularly rubber cultivation, can influence stream water acidity, potentially impacting aquatic organisms and ecosystem health.

Turbidity: Turbidity, a measure of water clarity, exhibited significant differences between streams in reserve forests and rubber plantations. In Pananchery, the mean turbidity in RF was 5.34 NTU, significantly lower than the mean turbidity in RPL at 7.77 NTU, with a p-value of <0.001. Similarly, in Poovanchira, RF had a slightly lower mean turbidity of 6.13 NTU compared to RPL (Fig. 4) and this difference was statistically significant with a p-value <0.001. The lower turbidity observed in streams flowing through reserve forests suggests that natural forest cover can act as a buffer against sediment runoff and maintain clearer water.

Table 1
Selected physico-chemical parameters of stream water at Pananchery and Poovanchira

Parameter	Pananchery (mean)			Poovanchira (mean)		
	RF	RPL	P-value	RF	RPL	P-value
DO (mg/L)	5.87	4.41	<0.001	5.34	4.66	0.090
pH	6.58	7.07	0.030	6.69	6.58	0.510
Turbidity(NTU)	5.34	7.77	<0.001	6.13	6.72	<0.001
Nitrate	0.77	0.84	0.250	0.81	0.75	0.390
EC (µS/cm)	102.43	112.14	0.020	107.57	108.57	0.850
Total coliform	14.57	24.14	0.010	14.43	39.29	0.010

Fig. 3: DO level in stream water

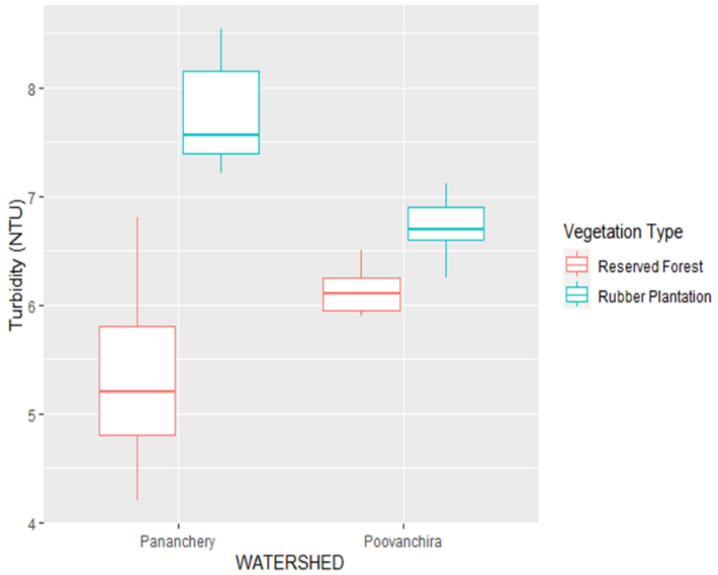

Fig. 4: Turbidity level in stream water

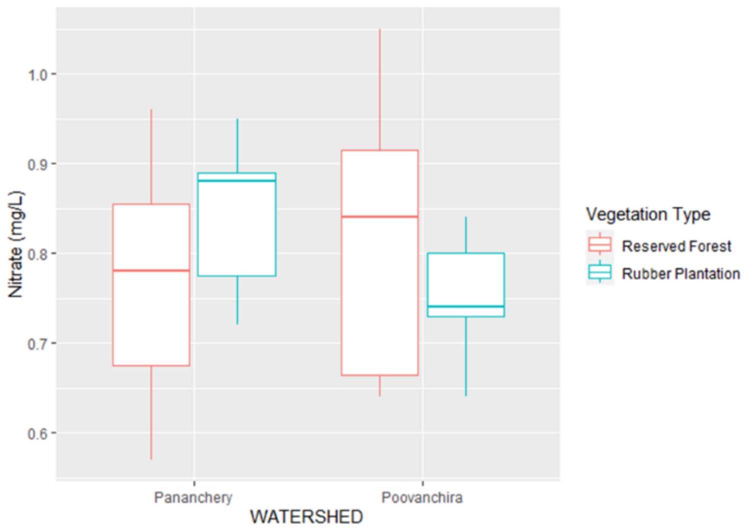

Fig. 5: Nitrate level in stream water

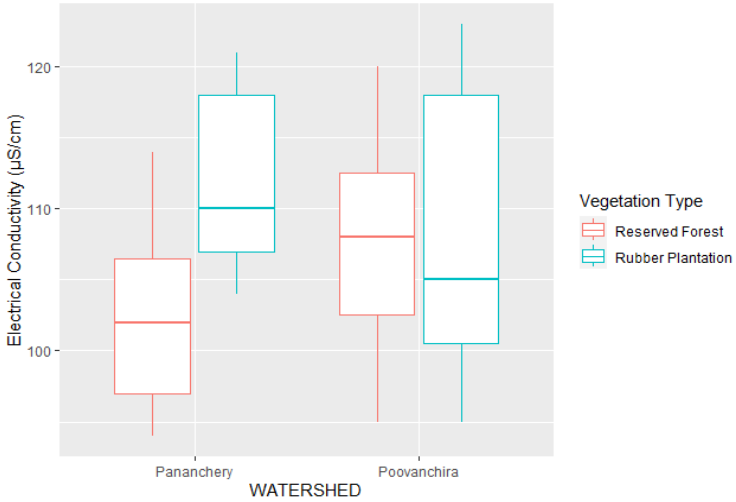

Fig. 6: Electrical Conductivity in stream water

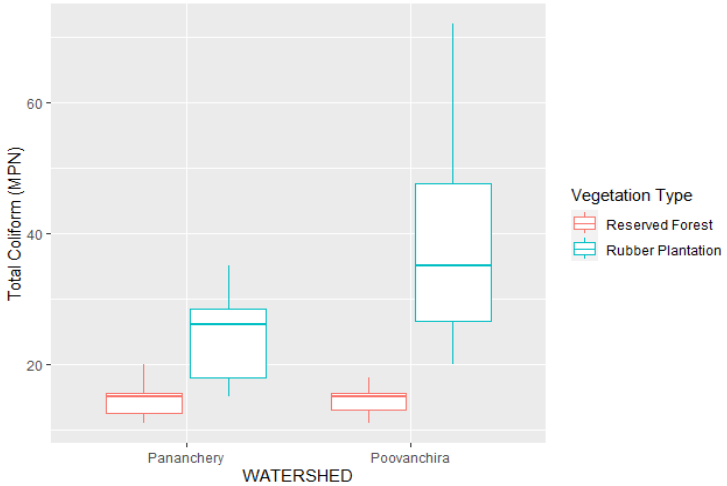

Fig. 7: Total Coliform Bacteria in stream water

Nitrate levels: There was no significant difference in mean nitrate levels between streams in reserve forests and rubber plantations in both Pananchery and Poovanchira sites (Fig. 5). The p-values for nitrate levels in Pananchery and Poovanchira were 0.250 and 0.390 respectively. These results indicate that the two land use types do not have a substantial impact on nitrate levels in the streams studied. However, further research may be needed to investigate other potential sources of nitrates and their impact on water quality.

Electrical Conductivity (EC): In Pananchery, the mean electrical conductivity (EC) in RF was 102.43 µS/cm, significantly lower than in RPL with 112.14 µS/cm, with a p-value of 0.020. However, in Poovanchira, there was no significant difference in mean EC between RF (107.57 µS/cm) and RPL (108.57 µS/cm), with a p-value of 0.850. EC is an indicator of dissolved salts and minerals in water and lower EC values in reserve forests suggest lower levels of pollutants and salts, contributing to better water quality.

Total Coliform bacteria: The mean total coliform count in streams flowing through reserve forests was significantly lower than in streams flowing through rubber plantations in both Pananchery and Poovanchira sites. In Pananchery, RF had a mean total coliform count of 14.57 CFU/100 mL, significantly lower than RPL with 24.14 CFU/100 mL, with a p-value of 0.010. Similarly, in Poovanchira, RF had a significantly lower mean total coliform count of 14.43 CFU/100 mL compared to RPL with 39.29 CFU/100 mL with a p-value of 0.010. These results indicate that reserve forests exhibit lower levels of total coliform bacteria, which are indicators of potential fecal contamination and waterborne diseases.

In summary, the results of this study demonstrate significant differences in water quality parameters between streams flowing through reserve forests and those flowing through rubber plantations. Reserve forests contribute positively to water quality by maintaining higher dissolved oxygen levels, lower turbidity, lower electrical conductivity and lower levels of total coliform bacteria compared to rubber plantations. These findings highlight the importance of preserving and restoring natural forest cover to protect water resources and support healthy aquatic ecosystems.

Sustainable land and water management practices are essential to mitigate the adverse impacts of rubber cultivation on water quality and to ensure the ecological integrity of the Western Ghats region in Kerala, India. Further research on specific water quality parameters and long-term trends is necessary to inform effective environmental planning and conservation efforts in the region.

Discussion

The comparative analysis of land use patterns in Pananchery and Poovanchira revealed distinct differences, with Poovanchira having a larger area covered by reserve forests and Pananchery dominated by rubber plantations. These differences in land use are likely to have significant implications for water quality in the respective streams. Poovanchira's larger reserve forest area is expected to contribute positively to water quality in the streams flowing through it. Reserve forests play a crucial role in maintaining water quality by acting as natural filters, reducing sedimentation and regulating nutrient levels. The lower turbidity observed in streams within Poovanchira's reserve forests indicates clearer and cleaner water, which is beneficial for aquatic life and overall ecosystem health.

Additionally, the lower levels of total coliform bacteria suggest reduced risks of waterborne diseases and contamination, highlighting the importance of conserving these reserve forests to safeguard water resources. On the other hand, the larger area under rubber plantations in Pananchery raises concerns about potential negative impacts on water quality. Rubber cultivation often involves the use of agrochemicals such as fertilizers, pesticides and herbicides, which can lead to runoff into nearby water bodies. Such runoff can increase nutrient levels and pollutants in streams, leading to degraded water quality. The potential risks associated with agrochemical runoff emphasize the need for sustainable land and water management practices in areas dominated by rubber plantations.

While the study provided valuable insights into the general differences in water quality parameters between reserve forests and rubber plantations, further research is necessary to assess specific water quality parameters in greater detail. For example, the concentration of specific nutrients and pollutants, the presence of heavy metals and the long-term trends in water quality should be investigated to gain a comprehensive understanding of the impacts of land use on water resources.

To address the challenges posed by differing land use patterns in Pananchery and Poovanchira, it is essential to implement appropriate measures for sustainable land and water management. This may involve promoting agroforestry practices, such as intercropping rubber with native tree species, to reduce the environmental impact of rubber plantations. Contour farming and erosion control measures can help to minimize sediment runoff and soil erosion in both areas. Additionally, implementing strict regulations and monitoring systems to manage agrochemical use and prevent pollution is crucial for maintaining water quality.

Collaborative efforts among various stakeholders including local communities, government agencies, environmental organizations and rubber plantation owners, are vital for developing and implementing sustainable land and water management strategies. The aim should be to strike a balance between the economic benefits of rubber cultivation and the conservation of vital water resources and ecosystem services.

Conclusion

The contrasting land use patterns between Pananchery and Poovanchira have significant implications for water quality in the respective streams. The larger reserve forest area in Poovanchira is associated with improved water quality indicators, while the larger rubber plantation area in Pananchery raises concerns about potential water quality. Further research and collaborative efforts are necessary to assess specific water quality parameters and develop appropriate measures for sustainable land and water management and we can work towards preserving the ecological integrity of the Western Ghats region ensuring the availability of clean water resources for future generations.

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