



Recent Forest Degradation in Mountainous Sub-Watersheds of Sri Lanka: A Case Study of the Hirikatu Oya Sub-Watershed (2000-2022)

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Abstract

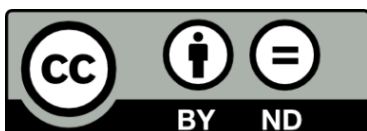
Forest degradation is a serious problem that requires the implementation of efficient management techniques to stop deforestation and safeguard the ecosystems worldwide. Even Sri Lanka faces the difficulties of managing its forest resources in every part of the country. The Hirikatu Oya sub-watershed, which is a very important water source area, is located in the Imbulpe Divisional Secretariat Division (DSD) in Sabaragamuwa Province. In recent years, this area has been affected by issues related to forest degradation, highlighting the need for immediate action. The objective of this study is to examine the status of forest degradation in the Hirikatu Oya sub-watershed from 2000 to 2022. A mixed-method strategy is used to accomplish this purpose. Supervised classification maps and NDVI-based data from Landsat 7 & 8 were used to evaluate and analyse the changes in the forest cover and the effects of human activities. According to the canopy cover change analysis, NDVI, field observations and interviews, severe forest degradation was observed in the Hirikatu Oya sub-watershed between 2000 and 2010. The canopy cover decline was 8.29%, which was mostly attributed to human-caused activities such as encroachments and illicit logging. From 2010 to 2022, forest fires, tree felling, changes to agricultural lands, and mining issues emphasise the urgent requirement for efficient management approaches to deal with forest degradation in the area. Ongoing efforts to reinforce management strategies, enforce pertinent regulations and implement targeted programmes, are needed to reduce the spread of invasive plant species as well as to encourage sustainable forest management in the sub-watershed.

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Keywords: Canopy cover, Forest degradation, GIS, NDVI, Sub-Watershed



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**Original Article****INTRODUCTION**

Forest degradation can be recognised as one of the pressing environmental problems in the 21st century. When a forest is degraded, its canopy cover, structure, or species composition declines, either temporarily or permanently. Currently, there are a number of studies relevant to forested land uses which underscores the importance of sustainably managing scarce forest resources. During the British colonial period (1881-1900), Sri Lanka's natural forest cover fell down from 85% to 70% of the country's total land area (De Zoysa, 2001). While the dry zone forest was cleared for lucrative timber, the central hills were converted for the cultivation of export crops. To develop a understanding of land and forest types and to formulate management strategies, the assessment of land and resource appropriateness for zoning and categorisation is necessary (De Zoysa, 2001).

Similarly, the forest reservation is one of the essential components in a watershed, and it has been contributing a lot of services to the watershed processes. The mountainous and highland areas should be covered by the forest, and this environment acts as a sponge to capture rainwater in the rainy season and release water in the dry season downstream. It is essential to maintain the river base flow and groundwater recharge at the lower areas for the survival of biodiversity. Land resources, water resources, forest

resources social environment, and technology are the main components of the watershed area. These components are interconnected and integrated with each other, and they perform a specific task within the watershed (Perera, 2019). Therefore, any kind of negative impact on a component will affect others too.

The Hirikatu Oya is a sub-watershed of the Walawe River in Sri Lanka, and it acts as a sponge capturing rainfall to gradually release water downstream, creating a permanent base flow. Accordingly, forest cover in this sub-watershed contributes to the sustainability of the downstream areas. The report "Drivers of Deforestation and Forest Degradation in Sri Lanka: Assessment of Key Policies and Measures" (Fernando et al., 2015) highlights the key causes of forest degradation as well as policy options for mitigating them. Bandara et al. (2019) studied the use of remote sensing and fragmentation analysis to assess forest cover loss and forecast future change, finding considerable deterioration in this protected area in the Wilpattu forest complex. Kaushalya (2021) revealed that there is a persistently high annual deforestation rate in Sri Lanka from 2000 to 2020. However, there are no similar studies conducted in the Hirikatu Oya sub-watershed recently. Therefore, this study aimed to analyse canopy cover and identify spatio-temporal variations of the forest degradation in the Hirikatu Oya sub-watershed during 2000-2022.

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The identification and analysis of forest degradation in the area, conducted using a mixed-methods approach, provide valuable insights for policymaking, sustainable land management, and conservation. Additionally, this approach supports the implementation of effective actions, enables progress monitoring, and contributes to the protection of the vital ecosystem services that forests provide. This investigation has been carried out to examine the status of canopy cover changes and forest degradation in the Hirikatu Oya sub-watershed, the interaction between forest and people, and the primary human activities that have contributed to forest degradation.

LITERATURE REVIEW

Through the literature review, the relationship between the current study and previous research is analysed to identify gaps. Local and international studies related to the current study (2000-2022) have been critically explored from various perspectives. This review aims to build a robust theoretical framework by critically assessing prior research, identifying key research areas, and addressing potential gaps, thereby establishing a solid foundation for this investigation.

Lamichhane (2008) studied land use and forest cover changes in Nepal's LundiKhola sub-watershed, employing supervised classification and socio-economic surveys to analyse driving forces of change. Mensah & Matthew

(2008) investigated forest degradation in Ghana using remote sensing (RS) and GIS techniques, analysing forest canopy classes and the influence of physical factors on degradation. Their study combined RS data with interviews, observations, and sample collections, demonstrating the utility of integrating diverse data sources for GIS-based mapping.

Sakthivel et al. (2010) examined forest cover changes in Tamil Nadu's Kalrayan Hills using high-resolution satellite imagery over 70 years. They observed that afforestation programs increased forest cover, while shifting cultivation and illegal encroachments reduced it. This study emphasises the potential of RS and GIS technologies in forest restoration planning. Further, using GIS map interpretations based on Geo Eye 1 satellite images, Perera (2017) identified that agro-well land development has been a threat to the stream reservations of the dry zone tank cascades in Sri Lanka, and there is a need to take mitigatory actions with proper agricultural planning. Yismaw et al. (2014) utilised Landsat data and NDVI classification to map forest cover changes in Ethiopia, revealing significant forest loss between 1973 and 2003.

Perera (2019) highlights the interdependence of forests and watersheds, describing forests as natural sponges that regulate river base flows, groundwater recharge, and biodiversity. The International Union

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for Conservation of Nature (2021) identifies deforestation and forest degradation as significant threats to ecosystems, advocating for nature-based solutions to mitigate these challenges. This underscores the critical need to study forest-watershed interactions within the Hirikatu Oya sub-watershed.

Thennakoon and Gamachchige (2021) explored traditional knowledge in forest preservation within Sri Lanka's Knuckles Range, identifying six criteria used by local farmers to detect forest degradation. Their study highlights the role of traditional methods in forest management.

Kumarasiri et al. (2021) evaluated soil erosion and forest quality impacts on water quality in the Samanalawewa Watershed using models like InVEST and NDVI analysis. Their findings demonstrated the critical role of healthy forest cover in enhancing water quality, which is directly relevant to the Hirikatu Oya sub-watershed, as it is connected to the Samanalawewa Watershed.

Canopy cover, which refers to the vertical projection of the tree structure and the layers formed by branches, is crucial in evaluating forest health. Korom et al. (2022) explain that canopy cover can predict stand volume for some tree species due to the relationship between crown and basal areas. Forest degradation, characterised by quantitative and

qualitative reductions in forest cover, directly impacts water supplies, as forests play a vital role in regulating water flow and supporting downstream sources.

Estoque et al. (2022) analysed global forest changes over six decades, revealing that deforestation resulted in the loss of 81.7 million hectares of forest between 1960 and 2019. They stress the importance of supporting low-income tropical countries in reducing deforestation while encouraging high-income countries to reduce reliance on imported tropical forest products. In addition to that, Estoque et al. (2022) highlight the essential role of forest ecosystems in maintaining biodiversity and providing ecosystem services, such as climate regulation and resource provisioning.

Further, Korom et al. (2022) reviewed forest degradation indicators, including canopy cover, below-ground biomass, and standing structure, highlighting the importance of these variables in understanding deforestation and promoting better forest management systems. The significance of canopy cover in determining forest stand volume and structure, especially for specific tree species. These concepts are integral to understanding the importance of forests in the Hirikatu Oya sub-watershed and how changes in canopy cover may signal forest degradation.



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As indicated by the prior literature, emphasising the global significance of forests, their relationship with watersheds, and the use of advanced technologies in monitoring forest changes, this research contributes to the sustainable management of forests in the Hirikatu Oya sub-watershed, safeguarding ecological integrity and local community well-being.

Although various studies have examined the forest degradation in Sri Lanka, these studies frequently focus on protected as well as major forest systems. However, no recent research has specifically examined forest degradation in the Hirikatu Oya sub-watershed, leaving a critical knowledge gap regarding localised canopy cover changes, selecting a Sub-watershed. The current study intends

to fill this gap by undertaking a systematic geographical and temporal analysis of forest cover loss and degradation in the Hirikatu Oya sub-watershed, giving site-specific information that can be used to assist long-term management and conservation planning in the area.

METHODOLOGY

Study Area

Hirikatu Oya (Figure 1) is one of the sub-watersheds of the Walawe River, which expands over 2105.55 ha. It is located in Imbulpe DSD, Rathnapura District, in Sabaragamuwa Province. It is marked as a biogeographically important zone in Sri Lanka due to the water source value and eco-system value.

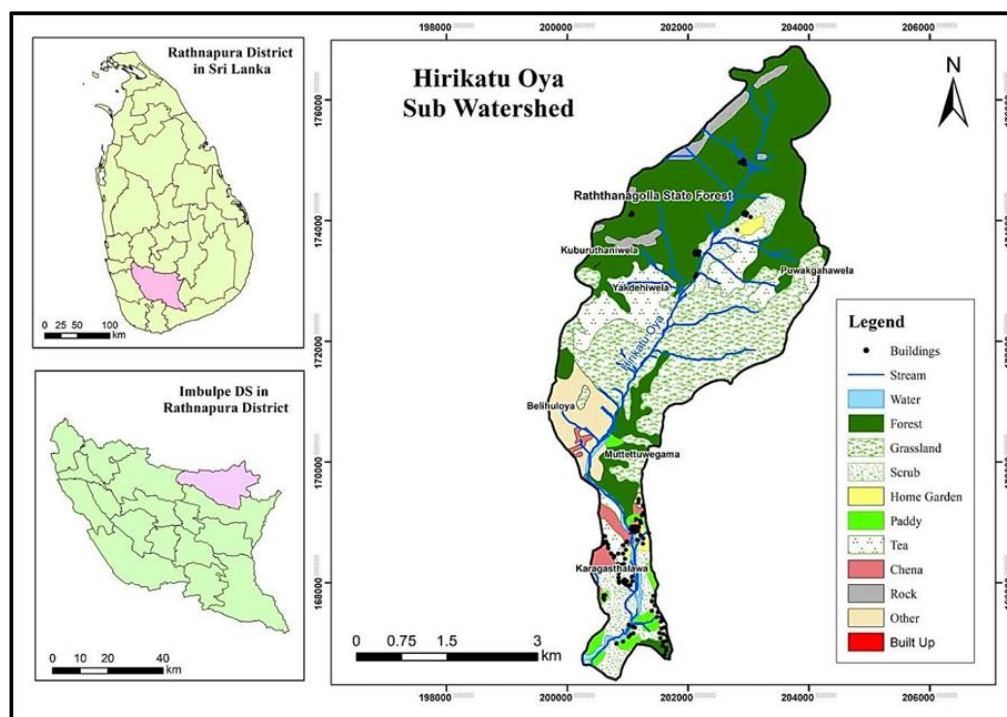


Figure 1. Hirikatu Oya sub-watershed
Source: Basnayaka & Perera (2025)



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Sub-montane forests, lowland-wet forests and grasslands can be mainly identified in the study area (Figure 1). The Hirikatu Oya sub-watershed is very important, and the influence of forests on the existence of the area. The total length of the Hirikatu Oya River is approximately 9 km. It originated from

the Yakdehiwala Grama Niladari Division (GND) and flows through the Muththetuwagama, Karagasthalawa GNDs and joins Belihul Oya River in the Kinchigune GND (Imbulpe Divisional Secretariat, 2021). After that it continues to flow as the Belihul Oya River to the Samanala Wewa Reservoir.



Exhibit 1. Natural forest areas and degraded forest areas in Hirikatu Oya sub-watershed
Source: Field observations, 12/03/2022

Various kinds of plant species can be identified in this area, including herbal plants (Ex: Iramusu (*Hemidesmus indicus*(L)R.Br), Hathwariya (*Asparagus falcatus*), timber plants (Ex: Badulla (*Semecarpus coriacea*), Milla (*Vitex pinnata*), invasive plant species (Ex: Havarinuga (*Astonia macrophylla*), Acacia (*Acacia nilotica*), threatened plant species (Ex: Ashoka (*Saraca asoca*), Sathsada (*Aristolochia indica*), and some endemic plant species like Maharathmal. Further, fauna species such as various types of birds, mammals, reptiles, and butterflies including deer, wild boars, leopards, rabbits, parrots, yellow birds, and different types of lizards like Ankattussa, which are endemic to this area.

Hirikatu Oya sub-watershed is predominantly located in Sri Lanka's

Intermediate Zone but also influenced by the Wet Zone due to its proximity to the Central Highlands. The average temperature of this area is around 25°C and due to the highlands in the north direction, the temperature drops below 20°C. The average rainfall of the area varies from 2000mm to 4500mm (Imbulpe Divisional Secretariat, 2021). The study area receives the rainfall during the south-west and north-east monsoon periods. During the monsoon season from June to September, average wind speeds exceed 12 km/h, with gusts reaching up to 31 km/h (Sabaragamuwa University of Sri Lanka, 2018). The area's steep slopes are affected by predominant southwest-to-northeast wind patterns, which increase erosion hazards following tree clearance

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(Sabaragamuwa University of Sri Lanka, 2018).

There are various types of soil varieties distributed in this Hirikatu Oya sub-watershed such as steep rockland and lithosols, red-yellow podzolic and mountain regosols: mountainous terrain, red-yellow podzolic soils: steeply dissected, hilly and rolling terrain, red-yellow podzolic soils with dark B horizon and red-yellow podzolic soils with prominent A1 horizon: rolling terrain.

Hirikatu Oya sub-watershed has a leaf shape and is characterised by a dendritic drainage pattern. The river is crucial for agriculture, as it supplies water for irrigation to some of the villages in the fertile plains of the Imbulpe DSD. Most of the surrounding areas are rural, and the river's water supplies are used to irrigate paddy fields, tea plantations, vegetables, and other crops. Tourists and nature enthusiasts are drawn to Hirikatu Oya and its surroundings by its beautiful splendour. The river is praised for its pure water, abundant vegetation, and scenic surroundings. This irrigation system supports the residents' agricultural livelihoods and enhances the region's total food output.

There are dense settlements in lowland areas and along main roadways. Higher elevations and mid-elevations have extremely low population density, owing to the forest cover and grasslands. In the study area, about 750 households (Imbulpe Divisional

Secretariat, 2021) are distributed as scattered and linear housing patterns.

MATERIALS AND METHODS

Data Collection

The study employed primary data collection methods such as questionnaires, interviews, and observations, along with secondary data sources including books, websites, research articles, Sri Lanka metric maps, and institutional reports such as resource profiles, Forest Department reports, and statistical documents.

Using questionnaires, information was collected on themes such as the spatial and temporal status of forest degradation in the Hirikatu Oya sub-watershed, the importance of the sub-watershed, and unsuitable human activities contributing to increased forest degradation. The survey covered 30 selected permanent resident households in the sub-watershed who had been living there for 30 years or more (prior to 2022). Data were collected using a random sampling method, selecting 10 families from each of the lower (450–600 m), middle (600–1200 m), and upper (1200–2100 m) parts of the study area. The watershed was divided into these three sections based on elevation.

Interviews were conducted with 2 GN officers, 2 agrarian officers, 1 wildlife officer, 5 forest officers, 1 environmental officer, and 2 NGO members over a period of 8 days,

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through visits to the relevant offices and premises. Moreover, field observations were conducted to identify the status of forest degradation. Initially, the study area was examined using Google Earth historical images and metric maps from the Survey Department of Sri Lanka. Subsequently, field visits revealed various anthropogenic activities, such as human constructions and agricultural land use, that disturb the Hirikatu Oya sub-watershed. These observations were documented with photographs as evidence of the problematic conditions and forest degradation in the area.

Secondary data included topographic maps from the Survey Department of Sri Lanka, research articles and books on forest degradation in similar regions, annual reports from the Range Forest Office in Balangoda, and village resource profiles from the Imbulpe DSD. Further details regarding the status of forest degradation and its contributing factors were obtained from the Balangoda Range Forest Office. Additionally, data on population and economic activities were collected from the GN offices in Muthetuwagama, Yakdehiwala, Karagasthalawa, and Kinchigune. Satellite images from Google Earth Pro and USGS Earth Explorer were also used to analyse temporal forest cover, land use changes, and NDVI variations.

In the qualitative analysis stage of the research, processes such as identifying,

examining, interpreting, and transcribing data were undertaken. The study focused on understanding temporal and spatial changes in forest cover and forest degradation. It also examined the nature of forest damage, the underlying causes, the problems exacerbated by degradation, and the influence of other land uses on forest ecosystems. Furthermore, the analysis explored community perspectives, including motivations for forest resource management, the benefits derived from forests, and the factors that encourage local communities to engage in forest conservation.

Furthermore, the present study utilised historical imagery from Google Earth Pro to identify the Hirikatu Oya sub-watershed and to examine the status of forest degradation from 2000 to 2022, with the aim of identifying spatial and temporal changes in forest cover. Google Earth Pro images and 1:50000 metric maps were used to identify the watershed boundaries and other land use distributions of the case study area. The Landsat 7 & 8 satellite images covering the dry months of January and February in 2000, 2010 and 2022 were also used in the study. Google Earth Maps were used to identify other land use distributions and how they affect forest degradation. Data on the status of forest degradation, its causes, and the problems arising from it were obtained through questionnaires, interviews, and field observations. The data collected are presented through charts, graphs, tables, and GIS maps. In



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addition, the information obtained from institutional reports was analysed through statistical measures (e.g., percentages, modes, averages) under quantitative analysis techniques.

The study utilized NDVI classification and supervised classification to identify the recent changes of canopy cover and the status of forest degradation. "NDVI is a nonlinear function that ranges between -1 and +1. Healthy vegetation has high positive NDVI values because of its relatively high reflectance in the NIR and low reflectance in the visible wavelengths" (Yismaw *et al.* 2014). While a score close to 1 denotes lush green vegetation, a value close to -1 denotes the presence of clouds or water. Values near 0 denote a lack of vegetation or barren ground (Auravant, 2021). Following are the formulas used for canopy cover changes and NDVI computation:

$$R = \frac{a - b}{t} \text{-----} [1]$$

Where,

R = Rate of forest cover change

a = Recent year forest cover (ha)

b = Initial year forest cover (ha)

t = Number of years between a and b

Source: Yismaw *et al.* (2014)

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \text{-----} [2]$$

Where,

$NDVI$ = Normalised Difference
Vegetation Index

NIR = Light reflected in the near-infrared spectrum

RED = Light reflected in the red spectrum

Source: Auravant (2021)

RESULTS AND DISCUSSION

Canopy cover changes in the Hirikatu Oya Sub-watershed

The Hirikatu Oya sub-watershed's change in canopy cover has been shown on the map below using three years (2000, 2010, and 2022), and Landsat 7 & 8 data have been utilised to create the following maps (Figure 2).

When the canopy cover is taken in the year 2000, it can be recognised that the upper part of the sub-watershed is more spread out compared to the lower part of the Sub-watershed. The central section depicts a very low canopy spread, while a higher canopy spread can be discerned on the western side of the upper section. Low forest expansion can be identified on the eastern side. Taken as a whole, a maximum canopy cover depletion can be identified in the year 2010 compared to other years. By the year 2022, the deforestation had reduced. The main reasons for this were the conducting of tree planting programmes and the expansion of other forest plantations in the lower part of the Sub-watershed, which have fluctuated during the period 2010–2022.



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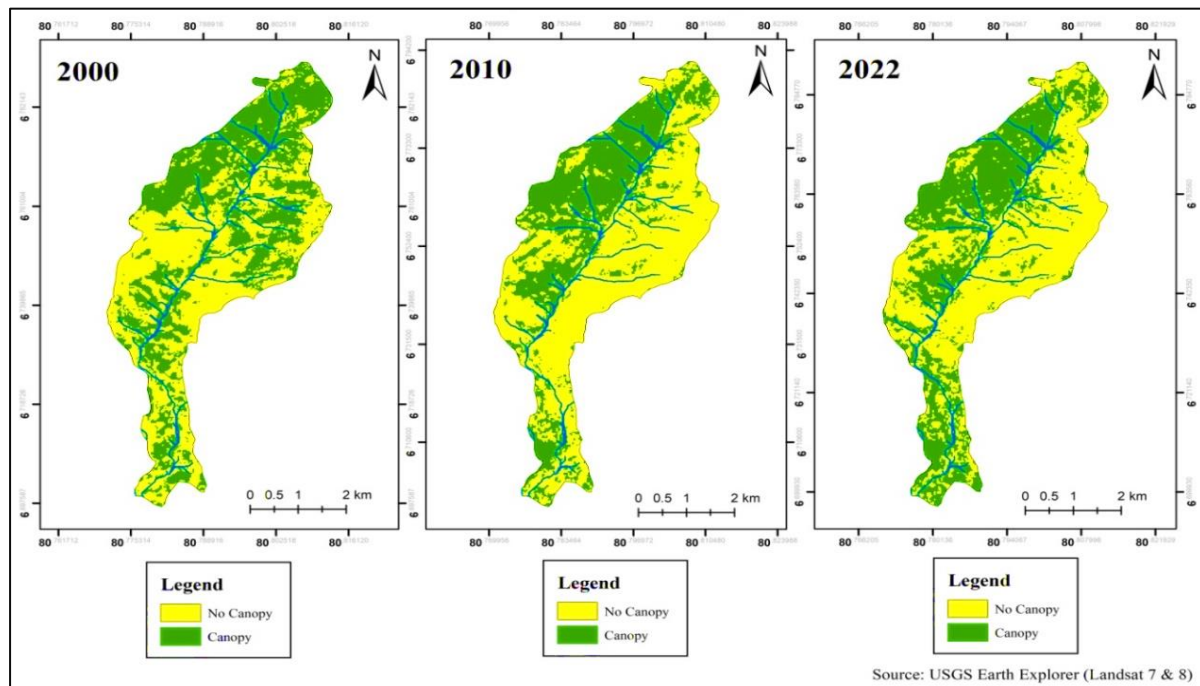


Figure 2: Canopy cover changes in Hirikatu Oya sub-watershed (2000, 2010 & 2022)
Source: USGS Earth Explorer (Landsat 7 & 8)

Table 1. Canopy cover status in the Hirikatu Oya sub-watershed (2000, 2010, & 2022)

Year	Canopy cover/Not	Area (Total area=2105.55ha)		
		Pixels	Sqm	ha
2000	No canopy	11959	10763100	1076.31
	Canopy	11436	10292400	1029.24
2010	No canopy	14103	12692700	1269.27
	Canopy	9292	8362800	836.28
2022	No canopy	12947	11652300	1165.23
	Canopy	10448	9403200	940.32

Source: Landsat 7 & 8 (USGS Earth Explorer)

There were 1029 hectares of canopy cover in the study area in 2000, and it decreased to 836 hectares in 2010. Surveys and interviews revealed that this decline in canopy cover was primarily caused by changes in land use. Additionally, site officials and other interviewed personnel noted that more management measures have been implemented in recent years compared to earlier stages. According to interviews, the effectiveness of

management measures implemented by governmental, non-governmental, and other organisations has contributed to an increase in canopy cover by 2022, which is further confirmed by the maps. From 2000 to 2022, the canopy cover decreased from 1029.24 hectares to 940.32 hectares, resulting in a total reduction of 88.92 hectares over the 22-year period. This indicates that the average canopy cover



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depletion rate during this time was 4.04 hectares per year.

The following Figure 3 depicts canopy cover changes in the Hirikatu Oya sub-watershed using percentage values.

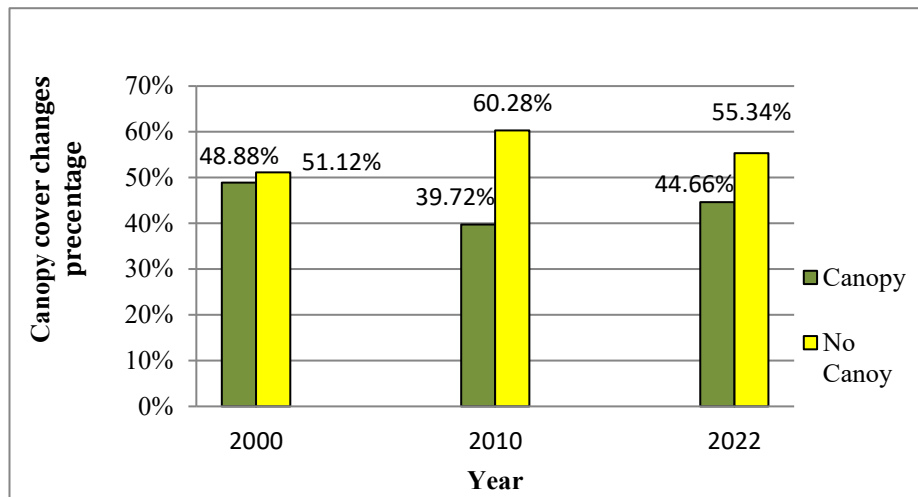


Figure 3. Canopy cover changes in Hirikatu Oya sub-watershed
Source: Google Earth Pro (2000, 2010, 2022)

The change in canopy cover of the Hirikatu Oya sub-watershed shows percentages of 49%, 40%, and 45% for the years 2000, 2010, and 2022, respectively (Figure 3). From 2000 to 2010, interviews and questionnaires revealed that the main reasons for the decrease in canopy cover were inadequate management measures, an increased incidence of human-induced forest fires, tree cutting, and a shortage of officials. After 2010, changes in land use and the expansion of agricultural land were the primary factors that affect canopy cover. However, by 2022, according to interviews, the implementation of recent management measures, improved performance of officers, and increased public

awareness contributed to an increase in canopy cover. Accordingly, the change in canopy cover by 2022 represents a positive increase of 5.85%, whereas the negative change from 2000 to 2010 was 8.29%.

NDVI-based Vegetation Classification of the Hirikatu Oya Sub-Watershed

In the Hirikatu Oya sub-watershed, the current health status and forest density were primarily depicted using NDVI maps. NDVI maps for the years 2000, 2010, and 2022 illustrate how the nature of the forest system has changed across space and time (Figure 4).



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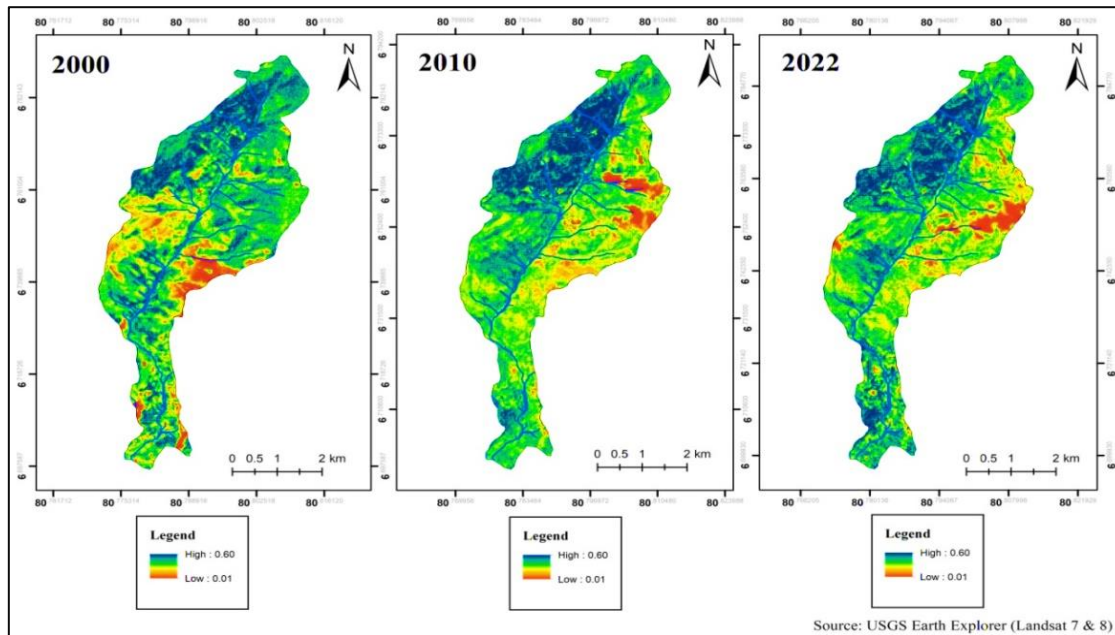


Figure 4. NDVI-based vegetation classification of the Hirikatu Oya sub-watershed (2000,2010 & 2022)

Source: Landsat 7 & 8 (USGS Earth Explorer)

In the year 2000, NDVI values for the forests indicate high vegetation density on the western side of the upper part of the Sub-watershed, while very low values are observed on the eastern side of the central part. By 2010, high NDVI values remain on the western side, whereas values on the eastern side have decreased. In the central part, compared to 2000, forest density has declined, and the lower part shows NDVI values at a normal level. By 2022, NDVI values in the upper part of the sub-watershed show an increase, while the eastern side remains very low. And by the year 2022, in the lower part of the catchment area, an average distribution can be identified in areas with increased density compared to the other two years.

Areas with very low density as well as normal-density areas can be identified in the mapped regions for all three mapping years. Accordingly, NDVI values provide information on the health status and forest density of the forest systems in the Hirikatu Oya sub-watershed. The NDVI values confirm the information obtained through interviews, questionnaires, and field studies about the status of forest degradation in the Hirikatu Oya sub-watershed, the changes in forest density, changes in forest characteristics, and changes in health conditions in the area. The following canopy cover maps show the vegetation classification types within the area in each year of the Hirikatu Oya sub-watershed (Figure 5).



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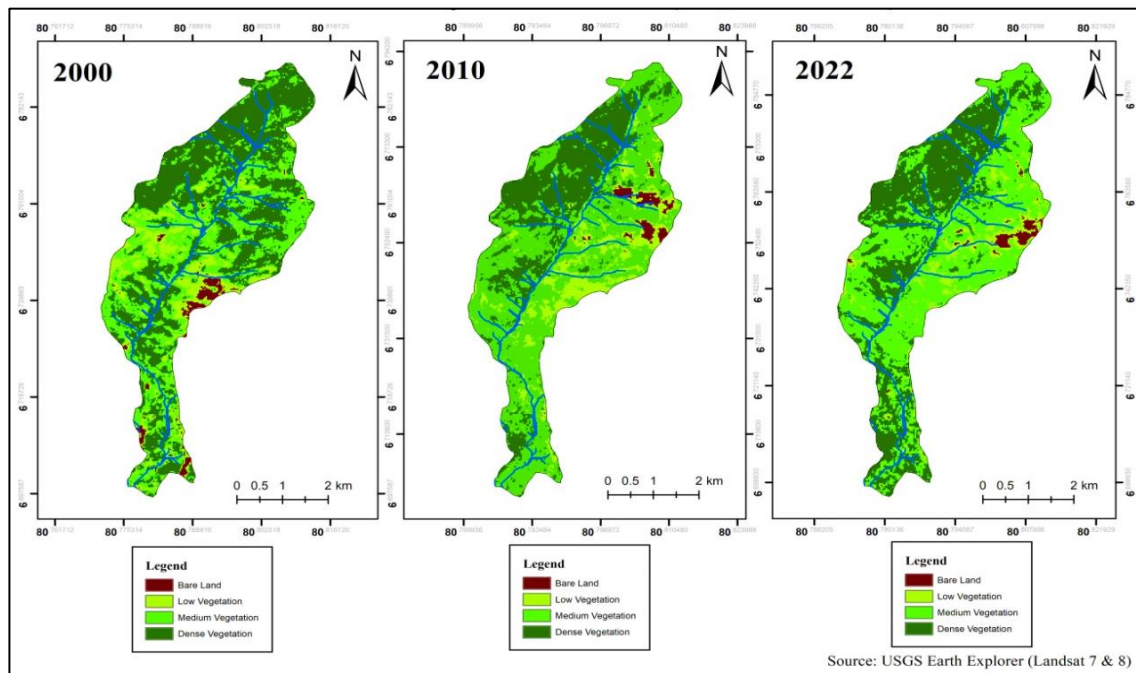


Figure 5. NDVI-based vegetation classification (2000, 2010 & 2022)

Source: Landsat 7 & 8 (USGS Earth Explorer)

Furthermore, the changes in vegetation cover of the Hirikatu Oya sub-watershed are illustrated through graph of vegetation classification prepared based on NDVI maps (Figure

6). Vegetation is classified into several types, including bare land, low vegetation, medium vegetation, and dense vegetation.

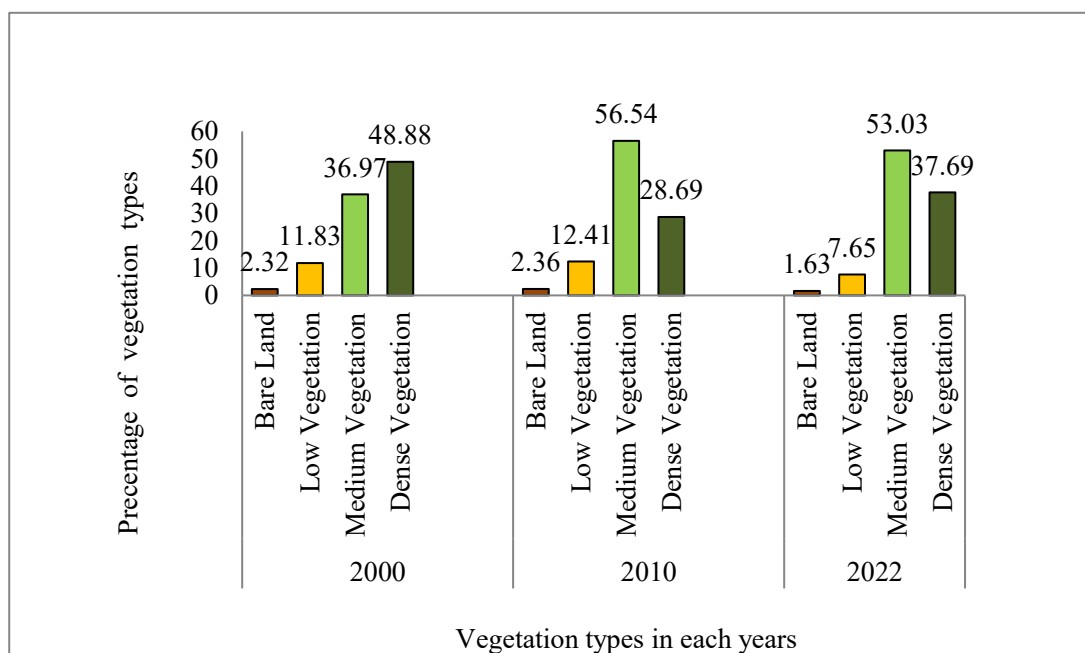


Figure 6. NDVI-based vegetation classification changes (%) during 2000, 2010, and 2022

Source: Landsat 7 & 8 (USGS Earth Explorer)



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The percentage of bare land in 2000 was 2.32%, which increased slightly to 2.36% in 2010. However, by 2022, the percentage of bare land had decreased to 1.63%. Thus, the increase in bare land by 2010 can be attributed to changes in land use, as well as the expansion of cultivated land and buildings. By 2022, the percentage of barren land had declined compared to previous years. The change in dense vegetation cover between 2000 and 2010 was 20.19%. By 2022, a positive increase in forest cover was observed, with a forest growth rate of 9% between 2010 and 2022.

Accordingly, analysis of these maps and other data revealed that forest degradation was particularly strong from 2000 to 2010. Although some degradation continued after 2010, by 2022, there was a decrease in forest loss and an increase in vegetation cover, indicating that management practices

have positively affected productivity. Therefore, it can be inferred that the results of management measures implemented both before and after 2010 contributed to these improvements.

The Relationship between Forests and Villagers in the Hirikatu Oya Sub-Watershed

The relationship between villagers and forest areas in the study region was investigated through questionnaires administered to residents within the officially demarcated villages of the sub-watershed. Respondents indicated that forests generally provide at least three benefits: medicinal plants, water resources, and timber (Figure 7). On the other hand, each village has a different arrangement for accessing these benefits.

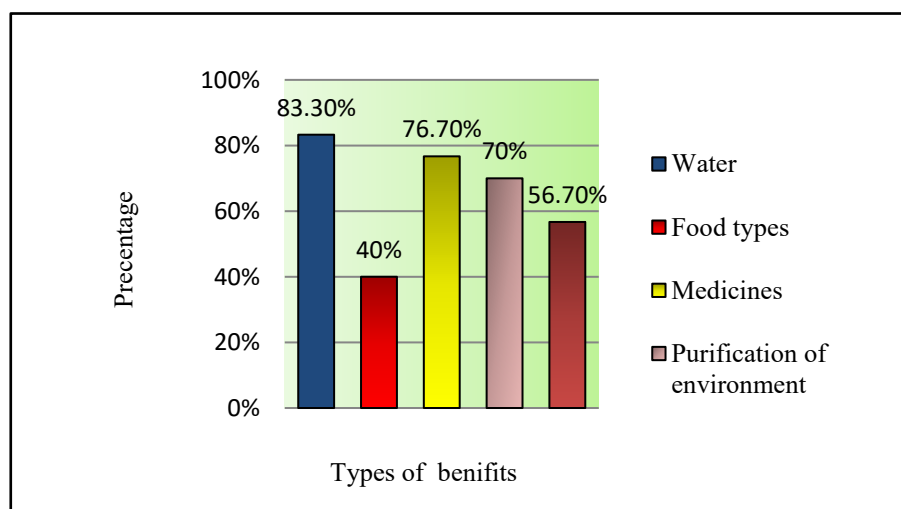


Figure 7. Positive Impacts of Forests on Livelihoods of Hirikatu Oya sub-watershed
Source: Questionnaire Survey, 2022

According to the questionnaire data, 76.70% of the people in the villages use

the forests for medicinal purposes. In addition, the villagers mainly meet

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their needs with wood. 56.70% of the forests are used for timber. The villagers mainly use wood for fuel and for building wooden appliances at home. On the other hand, about 40% of forests are used for food. The villagers relate to the forest for the above-mentioned benefits and are also aware of the ability of forests to clean the environment to a certain extent—about 70%.

However, questionnaires and interviews revealed that the existence of various types of lands adjacent to forests directly or indirectly contributes to forest degradation.

Anthropogenic Factors Affecting Forest Degradation in the Hirikatu Oya Sub-Watershed

This section emphasises the human factors contributing to forest loss in the Hirikatu Oya sub-watershed, alongside natural and other influences. According to the information gathered from the Forest Department, NGOs, and other government representatives, the destruction of the forests in the Hirikatu Oya sub-watershed has been influenced mainly by human activities.

The facts revealed through the analysis of the data obtained from the interviews and questionnaires were that, from 2000 to 2010, forest degradation had been caused by human-oriented forest fires, land and water pollution, and land use changes with agricultural and settlement expansion. According to the

Community Forest Management Programme Plan (2013–2015) on forest crime records for the past 5 years, these threats were identified: forest fires, unauthorised burning, unauthorised transportation of wood, unauthorised mining, and unauthorised logging.

Human-Oriented Forest Fires

The analysis revealed that human-caused forest fires are the primary cause of forest degradation in the Hirikatu Oya sub-watershed. The area around Hirikatu Oya is mainly covered by lowland wet forests and sub-montane forests, which are highly biodiverse. The mountainous region where the river near Hirikatu Oya originates is predominantly forested, with pine plantations also widespread. The water catchment function of the area is seriously threatened due to annual fires. Maintaining good forest cover in the upper reaches of the river is essential for preserving the health and sustainability of the sub-watershed.

“Every year, before the south-west monsoon rains, in the months of January to February, and in the months of August and September before the north-east monsoons, there are many fires on the eastern slopes of these mountains. Almost all of these fires have been identified as human-caused. There are several main types of fires. Those are recreational fires, indiscriminate burning by tourists, and fires intentionally set for agriculture or



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foraging, such as to create new grass for cattle, clear land for tea cultivation, aid in hunting, or to harvest produce like Nelly and yams and collect honey from bees. The fires are set indiscriminately in the lands adjacent to the forest. The Forest Department is making significant efforts to control these fires, which are essential for protecting and enhancing the forest cover in this area. Law enforcement in this regard has not been very successful, mainly because the fires often spread before they can be contained. Therefore, the Department is working to prevent and suppress forest fires by educating local adults and school children about the importance of protecting the environment.” (Forest Extension officer, Balangoda, 15/03/2022)



Exhibit 2. A view of the fire that spread in the Panugalgoda area at the foot of Belihuloya, Pabahinna and Paraviyangalakanda

Source: Haritha Mithuru Society, 2021



Exhibit 3. A view of the forest area in the Panugalgoda area at the foot of Belihuloya, Pabahinna and Paraviyangalakanda in 2022

Source: Field observation, 13/03/2022

It is obvious that human-induced fire is the primary cause of the forest fires in the Hirikatu Oya sub-watershed. Since 2000, forest fires have occurred almost annually, primarily caused by human activities.

“Most of the time, people visiting Hirikatu Oya from outside either carelessly or intentionally start fires in the forest area. They leave behind used cigarettes, which spread fire in the forest. Fires spread quickly due to the presence of pine trees. There are always fires in the water catchment area during the dry season, particularly between August and September. Recently, some boys went hunting and joined with other groups for fun, and they set fire to the forest” (Retired GN Officer, Karagasthalawa, 22/03/2022).



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However, there are no records of forest fires in this region during 2022. Interviews and questionnaires revealed that villagers' awareness of the issue and their active participation in forest protection were the key contributing factors. In addition, the activities of the range forest officers provided further support in achieving this outcome.

Land and Water Pollution

Another major problem noticeable in the forest of the Hirikatu Oya sub-watershed is the illegal dumping of trash, mostly by local visitors who come to bathe or sightsee. In the nearby woodland region, pollution is evident. In this way, biodiversity has suffered as a result of the informal disposal of waste (polythene, glassware, and other perishable materials) in the region surrounding the forest (Exhibit 4). When trash is left scattered in the forest and surrounding areas, it disrupts the natural balance of the ecosystem. Harmful substances from the waste can leach into the soil and water, contaminating the environment and negatively affecting the plants and animals living there.

"People who come to see and bathe in Hirikatu Oya leave plastics, glass, and other waste in the river area. There is no proper way to dispose of the glass and other materials. So far, no institutions have taken any concrete steps. Some voluntary organizations remove the waste

every three months, but not all of it gets cleared." (Retired GN officer, Karagasthalawa, 22/03/2022).



Exhibit 4. Land and water pollution in Hirikatu Oya sub-watershed

Source: Field observation, 09/03/2022

One of the key findings inferred from observations, questionnaires, and interviews in the study area was that the pollutants were primarily found on the ground and in the water in the forest area of the Hirikatu Oya sub-watershed. There are numerous wastes thrown there, mostly by outsiders, and the locals, together with other governmental agencies and NGOs, have taken several actions to stop it at least partially. However, the mixing of pollutants has created a situation that is harmful to the environment, aquatic ecosystems, and diversity of plant community.

Land Use Changes Due to Agricultural and Settlement Expansion

Settlement distribution, home gardens, roads, and other land use patterns have mainly contributed to forest



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degradation in the study area. According to the findings, land use changes have been a major driver of forest degradation in the Hirikatu Oya sub-watershed, particularly since 2010. The expansion of houses, road networks, and plantations from 2010 to 2022, compared to 2000–2010, has had a significant impact on forest loss. The extraction of wood for house construction, the shift toward tea cultivation, forest clearance for settlements, tourism-related development, and other infrastructure

projects have been identified as the main causes of forest degradation.

The main finding revealed through questionnaires, interviews, and observations was that, with people turning to tea cultivation, there has been increased expansion of these plantations near the forests. Additionally, some people have encroached into the forest to cultivate pepper and tea plantations. Thus, agriculture-related activities also contribute to forest degradation in this study area (Exhibit 5).



Exhibit 5. An area of Forest Cleared for Tea, Pepper, and Sand mining.

Source: Field observation, 10/03/2022

Accordingly, it can be identified that the factors discussed above are the main causes of forest degradation in the Hirikatu Oya sub-watershed. The following graph (Figure 8) shows the intensity of the factors affecting forest degradation in the Hirikatu Oya sub-watershed, based on villagers' opinions. The graph represents the situation from 2000 to 2010 and from 2010 to 2022.

During the years 2000–2010, about 83% of the data related to forest fires, 40% to tree cutting, 50% to changes in land use, and 36% to other factors such as mining. Consequently, fires were the main cause of forest destruction during this period. Between 2010 and 2022, forest degradation was caused by fires in approximately 70% of cases, while changes in land use emerged as the leading cause, accounting for 76.7% of forest destruction.



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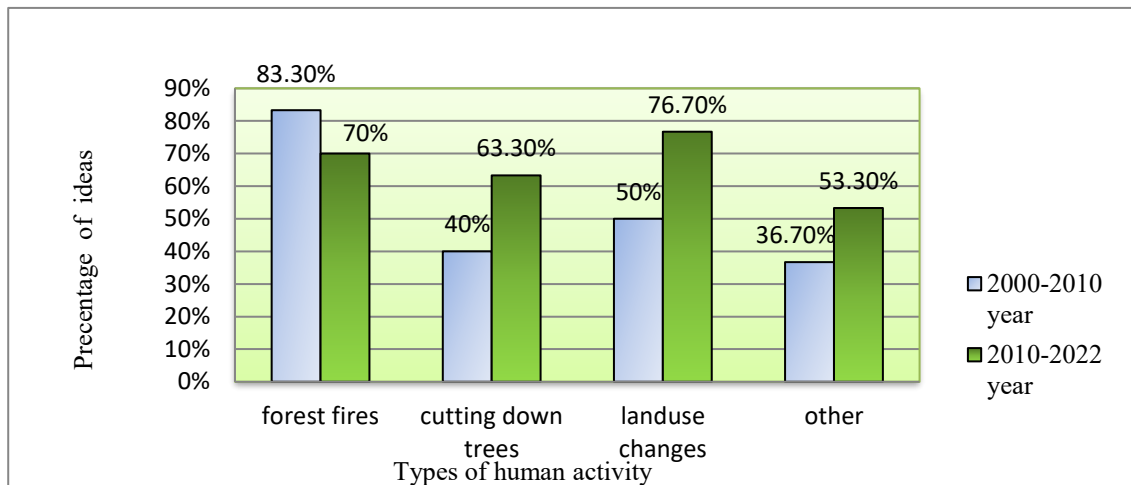


Figure 8. People's perceptions of human activities that contributed to forest degradation in the study area

Source: Questionnaire survey, 2022

From 2010 to 2022, compared to the years 2000–2010, it is evident that more trees were cut down due to population growth and road construction, with 63.3% of trees being removed. Some factors had a greater impact on forest degradation between 2010 and 2022 than others, with the influence of other

elements varying by 16.6% between the two periods. However, it is clear that changes in land use were primarily responsible for forest loss during 2010–2022. Accordingly, this study highlights that human activities have a significant impact on forest degradation (Figure 9).

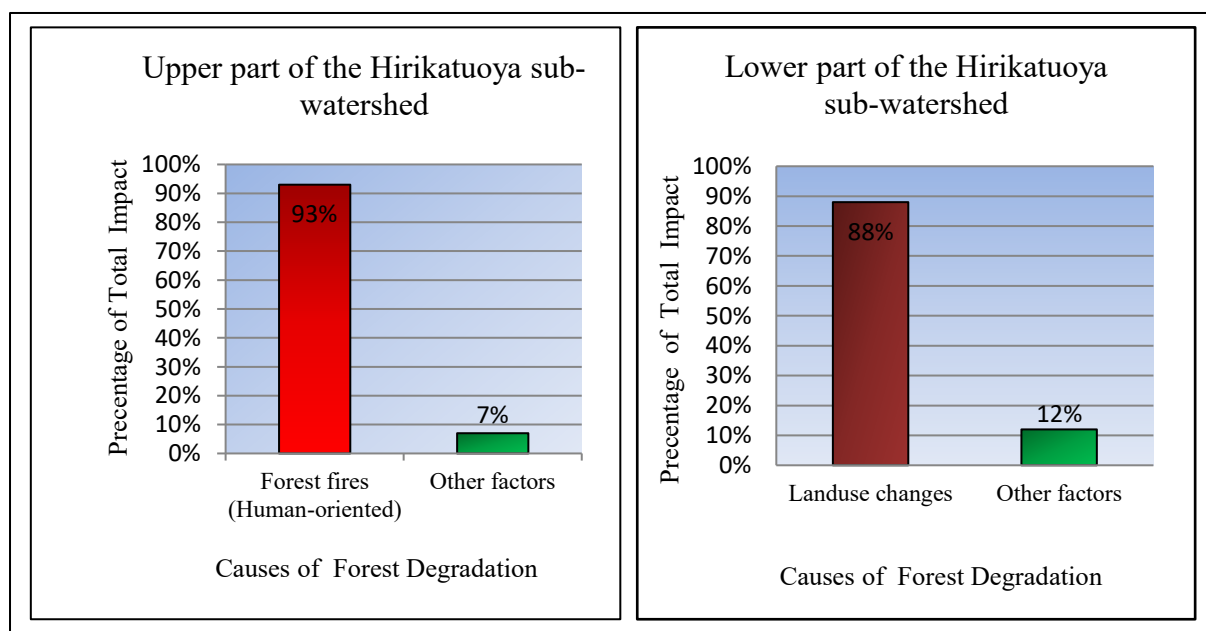


Figure 9. Human Drivers of Forest Degradation in the Upper and Lower Parts of the Sub-Watershed

Source: Questionnaire survey, 2022

**Original Article****CONCLUSION**

This study primarily focuses on recent forest degradation in a mountainous sub-watershed in Sri Lanka, specifically the Hirikatu Oya sub-watershed, over the period from 2000 to 2022. Forest degradation was assessed using forest structure indicators, such as canopy cover changes and NDVI.

Questionnaires, interviews, and field studies revealed the presence of forest degradation in the Hirikatu Oya sub-watershed, which was further confirmed through maps. The study also examined changes in canopy cover and the overall health of the forest system in the sub-watershed.

The main causes of forest degradation in the area have been identified as human-caused forest fires, tree cutting, land use changes, and other factors. Population expansion, road building, and increased tree cutting have all significantly contributed to the region's growing environmental challenges, particularly between 2010 and 2022. The natural balance of the forest and its vital role as a water catchment area must be protected, and these findings highlight the urgent need for extensive and focused conservation actions. Due to human-driven activities, several mountainous sub-watersheds, such as the Hirikatu Oya sub-watershed in Sri Lanka, have experienced considerable degradation and challenges in maintaining the sustainability of their forest environments.

To preserve the long-term viability of the forest ecosystem in the Hirikatu Oya sub-watershed, a series of integrated conservation strategies are required. At the same time, applying sustainable forest management methods and conducting frequent monitoring can help promote healthy regeneration. Comprehensive land-use planning, such as establishing buffer zones and fostering agroforestry, will reduce human intrusion while improving natural balance. Manual removal, biological control, and native vegetation restoration should be included in targeted initiatives to manage invasive plant species, with research and community involvement supporting the efforts. Finally, raising public awareness through education, workshops, and community-based forest management can develop a sense of ownership and promote sustainable practices. These steps will help to preserve the forest resources of the Hirikatu Oya sub-watershed for future generations.

The Hirikatu Oya sub-watershed can make substantial progress in preserving its priceless forest environment by following these thorough recommendations. Collaboration amongst different stakeholders, including local communities and law enforcement organisations, will be crucial to the success of these conservation efforts. The Hirikatu Oya sub-watershed can remain a crucial ecological enclave with



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continued dedication, education, and prudent management techniques.

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