Addressing Environmental Vulnerability: Land Cover Dynamics Assessment and Afforestation Strategies in Pakistan for Disaster Resilience

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Abstract. Pakistan has a limited forest cover. The present condition of forests in Pakistan indicates a profound apathy. The devastating floods of 2022 in Pakistan killed 1,739 people and caused 15.2 billion USD in economic losses, underscoring the urgent need for proactive environmental management strategies. This study investigates land cover changes, focusing on forest cover, in Pakistan from 2017 to 2023, aiming to inform policy and mitigation efforts. High precipitation intensity from July to August 2022 exacerbated the impact of the floods, revealing the region's vulnerability. The method uses spatial analysis from Existing artificial intelligence (AI) land classification models, which were enhanced by bringing together a massive training dataset of billions of human-labeled image pixels. The analysis reveals a stark reality: Pakistan's forest cover is a mere 2%, highlighting the critical need for intervention. Examining land cover dynamics over the six years illuminates trends and projections crucial for environmental planning. Protecting existing forest cover along with Government-led afforestation initiatives underway signal a proactive response, intending to bolster environmental resilience and reduce the susceptibility to natural disasters. Insights gleaned from this research serve as a foundation for strategic policy formulation, guiding efforts to enhance environmental quality and safeguard against future calamities in Pakistan.

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1 Introduction

Pakistan is a poor forest resource country primarily because of the arid and semi-arid climate in the larger part of the country and is witnessing excessive degradation [1]. According to various guesstimates, Annual deforestation rates ranged from 0.7% to 2% [2–4]. Many forests were lost in the 17th century, and the state of affairs was different from what it was 300 years before. For example, today's reality is the illegal forest cutting that has left Pakistan's Himalayan hills barren. There was no scientific-based policy for forest protection before the British administration. The idea of property had not yet matured, and people believed rulers owned the forests and possibly the entire land. Forest utilization was conducted based on their needs before the British rule in 1843.

Forest conservation laws were created for the Hazara and Murree peoples in 1856 and 1857. Then, unless approved, all tree-cutting and felling were outlawed, and no more land could be granted to individuals for farming. It marked the beginning of thoughtful science. The government created the "Forest Act" in 1865. Reserved forests and Guzara forests were the two types of forests possessed by the government in 1872. There was no such thing as a scientific management approach before this. Thus, a working plan was created, and some fundamental guidelines were established in the first forest policy directive. As a result, the forestry sector develops education programs and maps its forests. Thus, forest research and study were initiated at Dehra Dun, India, in 1878.

Following the country's 1947 declaration of independence, the first forest policy was announced in 1955. Additional suggestions were made in 1962 and 1975. A National Agricultural Policy was recently formed in 1991; it differs from the 1955 policy in that it includes instructions for a Forest Management Plan, which was later implemented [5]. A diversity of ownership structures exist for forests in Pakistan. Forests are classified legally as private (not owned by the state) or public (owned by the state). Based on the Food and Agriculture Organization (FAO) report in 2020, Pakistan's natural forest cover (state-owned) is currently only 2.2% [2]. A land-use system based on trees in hilly and marginal regions of arid and semi-arid climates is more cost-effective. It can support a larger human population than agriculture and other sustainable land-use systems in the long term [6]. However, for poor people, immediate living is of greater significance than long-term sustenance.

The devastating flood in 2022 in Pakistan claimed more than 1,000 lives and incurred economic losses of 15.2 billion USD, illustrating the importance of proactive environmental strategies in Pakistan [7,8]. This flood mainly happened because of the high monsoon rainfall from July to August 2022, combined with the effect of climate change [8].

Climate change is an anomaly condition that causes the seasons to shift unpredictably, causing global warming, extremely hot or cold weather, biodiversity disturbance or loss, and potentially increasing the risk of flood or extreme drought [9]. The greenhouse gas effect mainly causes climate change. Greenhouse gases are produced mainly through human activities, such as carbon dioxide from the emission of industry and transportation, methane from farms, and nitrogen oxide from crop fertilizers. The future acceleration of global climate change is anticipated due to a continuing upsurge in air temperature and atmospheric CO_2 levels. These changes ultimately lead to precipitation cycle and distribution variations [10,11].
(Bronisz, 2019; Bronisz & Mehtätalo, 2020; Jagodziński et al., 2017)(Grimm & Fisher, 1992) If human activities are kept as business as usual (BaU), the average temperature in the world will increase by 1°C in 2050, and the climate will be at a dangerous level [12]. Forest cover is crucial in mitigating climate change and global warming. This is due to its ability to absorb greenhouse gasses in the atmosphere and store carbon as biomass such as wood, litter, etc. [13–15].

Forests also reduce water surface runoff with their tree canopy and litter. Those phenomena will help the soil absorb the water surface better, increasing the groundwater storage to face the dry season. In addition, the root system in trees can help strengthen the soil and improve its ability to absorb more water. Therefore, forest cover is crucial to improving disaster resilience, especially from floods and landslides [16].

As climate change exacerbates the frequency and intensity of natural disasters, understanding and addressing land cover dynamics, particularly forest cover, becomes paramount for mitigating risks and fostering resilience. This study explores land cover changes in Pakistan from 2017 to 2023, employing advanced spatial analysis techniques and harnessing the capabilities of existing artificial intelligence (AI) land classification models [17].

By synthesizing insights from remote sensing data and qualitative interviews with key stakeholders, this research seeks to inform policy and mitigation efforts, offering a comprehensive understanding of the evolving environmental landscape in Pakistan. Numerous studies have highlighted the interplay between land cover changes and regions' vulnerability to natural disasters, underscoring the importance of proactive environmental management (Goheer et al., 2023; Hu et al., 2023). Moreover, the development of land cover change analysis is currently continuously improving, providing a precise and real-time spatial analysis [18].

This research is expected to have significant implications for policy formulation and environmental planning. It provides a solid foundation for strategic decision-making and guides efforts to enhance environmental quality and safeguard against future calamities. Through this integrated approach, the research seeks to generate actionable insights to inform evidence-based policy formulation and sustainable land management practices, ultimately contributing to enhanced environmental resilience and disaster risk reduction in Pakistan.

2 Method

2.1 Time and Place

This research was conducted using a desk study and data collection in Pakistan from March to May 2024.

2.2 Data Collection

A desk study was conducted to obtain data from ESRI Sentinel-2 10m land use/land cover data. This data was produced by Impact Observatory, Microsoft, and Esri. This layer displays a global map of land use/land cover (LULC) derived from ESA Sentinel-2 imagery at 10m resolution. Each year is generated with Impact Observatory's deep learning AI land classification model, trained using billions of human-labeled image pixels from the National Geographic Society. The global maps are produced by applying this model to the Sentinel-2 Level-2A image collection on Microsoft's Planetary Computer, processing over 400,000 Earth observations annually [17]. Additional data was obtained from articles, news, and reports from the Ministry of Climate Change and Environmental Coordination, Government of Pakistan.

2.3 Data Processing

The map data of this research process using the algorithm generates LULC predictions for nine classes, see Table 1. The year 2017 has a land cover class assigned for every pixel, but its class is based upon fewer images than the other years. The years 2018-2023 are based upon a more complete imagery set. For this reason, 2017 may have less accurate land cover class assignments than 2018-2023 [17].

Table 1. Class definitions of the land use/land cover

Value	Name	Description
1	Water	Areas with mostly permanent water.
2	Trees	An area containing tall (~15 feet) dense vegetation, usually with a closed or dense canopy.
4	Flooded vegetation	Any form of vegetation with visible water interspersion for most of the year; a seasonally flooded area with a mixture of grass, shrubs, trees, and bare ground.
5	Crops	Farmed crops.
7	Built Area	Man-made structures; major road and rail networks and buildings etc.
8	Bare ground	Barren regions devoid of vegetation throughout the year, characterized by scant to nonexistent plant cover; vast expanses of sand and deserts with minimal to no plant life.
9	Snow/Ice	Snow covered mountains and glaciers usually high altitude areas.
10	Clouds	No land cover information due to persistent cloud cover.
11	Rangeland	Vast areas supporting natural vegetation predominantly grasses and shrubs suitable for grazing and browsing by livestock.

These maps include Version 003 of the global Sentinel-2 land use/land cover data product. It is produced by a deep learning model trained by Artificial intelligence (AI) using over five billion hand-labeled Sentinel-2 pixels sampled from over 20,000 sites scattered through all key biomes worldwide. The underlying deep learning model uses six bands of Sentinel-2 L2A surface reflectance data: visible blue, green, red, near-infrared, and two shortwave infrared bands. To create a final map, the model is run on multiple dates of imagery throughout the year, and outputs are composited into a final representative map for each year. Input Sentinel-2 L2A data was accessed via Microsoft's Planetary Computer and scaled using Microsoft Azure Batch [17]. These data were then provided in the ESRI Sentinel-2 10m land use/land cover data and then processed with spatial analysis using ArcGIS.

2.4 Data Analysis

This dataset undergoes spatial analysis with a time series approach from 2017 into 2023, allowing for a comprehensive examination of land cover changes in Pakistan. Spatial analysis with time series involves analyzing geospatial data collected over multiple time points to discern patterns, trends, and changes in land cover dynamics. By utilizing this approach, the research aims to unravel the temporal evolution of forest cover and other land use categories in Pakistan, offering valuable insights into environmental change drivers and impacts [17,18].

Spatial analysis techniques, like remote sensing and Geographic Information Systems (GIS), were employed to process and analyze the extensive dataset comprising Sentinel-2

imagery collected over the study period. These tools enable the extraction of quantitative metrics, such as vegetation indices and land cover classifications, facilitating identifying and mapping changes in forest cover, agricultural land, urban areas, and other land use categories [19].

Furthermore, spatial analysis with time series offers opportunities for predictive modeling and scenario planning, enabling researchers to forecast future land cover changes and evaluate the effectiveness of alternative land management strategies and policy interventions [18]. By integrating spatial analysis techniques with time series data, the research aims to provide policymakers and stakeholders with evidence-based insights to inform decision-making and promote sustainable land use practices in Pakistan.

Overall, spatial analysis with a time series approach offers a powerful framework for understanding land cover change dynamics and environmental degradation over time. By leveraging geospatial data and analytical tools, this research seeks to advance knowledge on environmental change and support efforts to promote conservation, sustainable development, and disaster risk reduction in Pakistan [16,18].

3 Result

3.1 Pakistan Land Cover

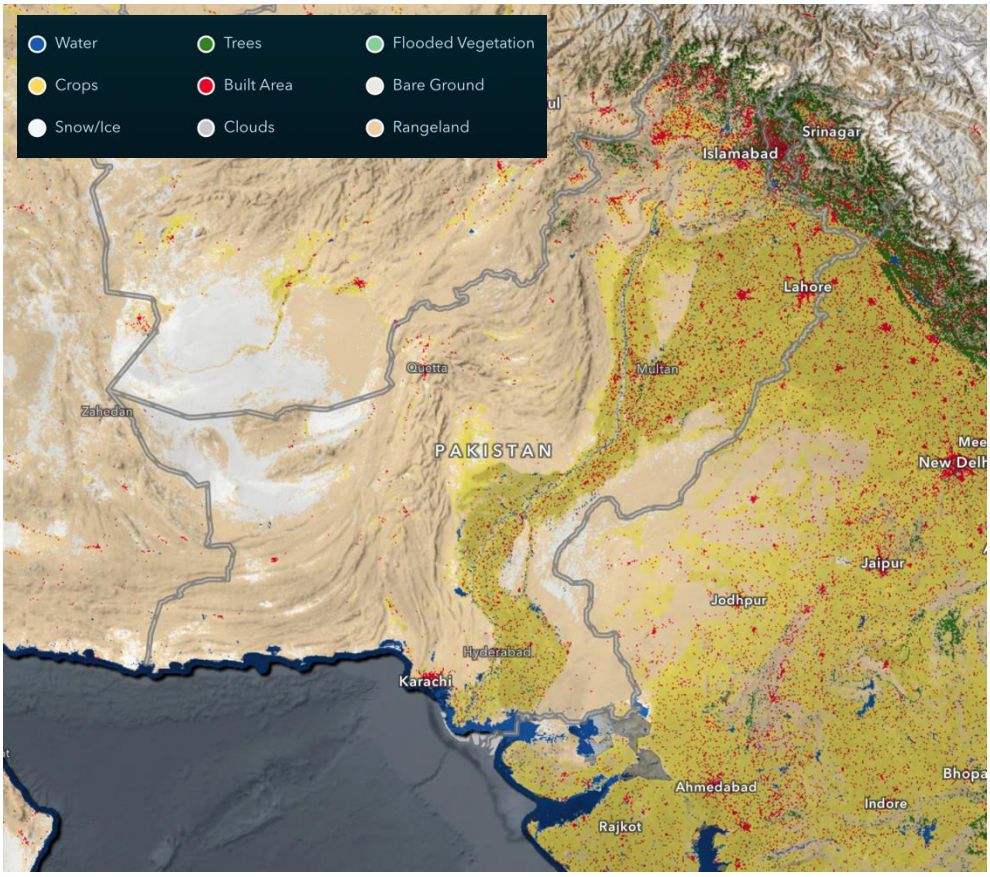

Fig. 1. Land cover in Pakistan in 2023

Figure 1 shows Pakistan's land use/land cover analysis generated by ESRI Sentinel-2 10m land use/land cover data. It can be seen that different land covers are defined by color. Blue represents water; green represents trees; light blue represents flooded vegetation; yellow represents crops; red represents built area; lavender represents bare ground; white represents snow/ice; gray represents cloud; and peach represents rangeland. Based on direct observation with bare eyes, it can be seen that Pakistan's land covers, especially in the western part, are dominated by mountainous bare round and rangeland. The forest cover can barely be seen.

Table 2. The land cover in Pakistan from 2017 to 2023

	Year						
Land cover	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Water	1,0%	1,0%	1,0%	1,0%	1,0%	1,0%	1,0%
Trees	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%
Flooded Vegetation	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%
Crops	22%	22%	22%	23%	22%	23%	23%
Built Area	3%	3%	3%	3%	3%	4%	4%
Bare Ground	19%	19%	17%	15%	17%	17%	11%
Snow / Ice	3%	2%	2%	3%	2%	3%	3%
Clouds	0%	0%	0%	0%	0%	0%	0%
Rangeland	51%	51%	52%	53%	52%	50%	56%

Table 2 shows detailed information about land use/land cover changes in Pakistan from 2017 to 2023. It can be seen that more than half of the land in Pakistan is covered by Rangeland. It happened because Pakistan has a large mountainous desert area. The second largest land cover is crop plantation, which reaches more than 20%. Pakistan is a unique country with a subtropical climate but can also plant tropical commodities such as rice. This happens due to it being a long summer with very high temperatures that can reach 50°C. Pakistan is the 5th largest populous country, with 250 million people [20]. No wonder this country has a large crop plantation area. The third largest land cover in Pakistan is bare ground. However, bare ground land cover seems to decrease every year and currently only reaches around 11%. This might happen due to increased land cover, built areas, and crop plantations [21]. Pakistan also has some areas covered with ice, around 3%. Forests cover only around 2% of Pakistan's total area. This might happen due to the high deforestation and illegal logging activity in Pakistan [21].

Even though the forest land cover percentage is very small, Pakistan can maintain it at 2%, not less. This success must also be appreciated because they can achieve zero net deforestation. It means that even though there is some deforestation in some areas, there are also some successful afforestation programs in other areas [22]. The afforestation program from the Ministry of Climate Change and Environmental Coordination, also from private forest (mainly agroforestry), has done well and needs to be continued on a larger scale. The larger and more massive afforestation program can help increase the forest cover in Pakistan, which is expected to reach 25% based on the recommendation from the Food and Agricultural Organization (FAO). If this condition can be realized, it will not be impossible for the upcoming disasters, such as floods, to be mitigated and the impact to be minimized.

3.2 Sindh Province

Sindh province is one of the most impacted areas by the 2022 flood in Pakistan. It is estimated that 799 people died and 8,422 people were injured in Sindh Province. Table 3

shows the land cover in Sindh Province, Pakistan, from 2017 to 2023. It can be seen that the forest cover is very small, only 0.2%, while the rangeland and crops have a very high number, around 40%. This condition is one factor that made this province so vulnerable to high rainfall and produced such a devastating flood in 2022.

Table 3. The land cover in Sindh, Pakistan, from 2017 to 2023

	Year						
Land cover	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Water	5,0%	4,0%	4,0%	5,0%	4,0%	4,0%	5,0%
Trees	0,3%	0,1%	0,2%	0,2%	0,2%	0,2%	0,2%
Flooded Vegetation	0,6%	0,3%	0,4%	0,6%	0,5%	0,5%	0,4%
Crops	38,0%	37,0%	36,0%	37,0%	37,0%	37,0%	38,0%
Built Area	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%
Bare Ground	12,0%	15,0%	16,0%	11,0%	11,0%	12,0%	7,0%
Snow / Ice	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Clouds	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Rangeland	42,0%	41,0%	41,0%	43,0%	43,0%	43,0%	47,0%

3.3 Baluchistan Province

Baluchistan Province is Pakistan's second-most impacted area after the devastating flood in 2022. 366 people died, and many infrastructures were destroyed, causing economic losses. Table 4 shows that eighty percent of this province is covered with desert or rangeland. The large desert in this province is known as the Kharan Desert. This condition is very dangerous and very vulnerable to disasters such as floods. Afforestation programs must be prioritized to improve flood resilience in this province.

Table 4. The land cover in Baluchistan, Pakistan, from 2017 to 2023

	Year						
Land cover	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Water	0,2%	0,2%	0,2%	0,2%	0,3%	0,2%	0,3%
Trees	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Flooded Vegetation	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Crops	2%	2%	3%	3%	3%	3%	4%
Built Area	0,2%	0,2%	0,3%	0,3%	0,3%	0,4%	0,4%
Bare Ground	29%	26%	22%	19%	20%	23%	15%
Snow / Ice	0%	0%	0%	0%	0%	0%	0%
Clouds	0%	0%	0%	0%	0%	0%	0%
Rangeland	68%	71%	75%	77%	76%	73%	80%

3.4 Islamabad

Islamabad is the capital of Pakistan [20], and it is one of the cities that was not impacted by the flood in 2022. Table 5 shows the land cover data of Islamabad from 2017 to 2023. It can be seen that Islamabad has a huge forest cover, reaching more than 20%, and it rose slightly from 2017 to 2020. This might be one of the factors that prevented Islamabad from being very impacted by the devastating flood in 2022. Trees play a very

important role in minimizing floods. It can slow down the water's surface run-off so the soil can easily absorb the water. The forest can also form a microclimate to minimize extreme rainfall or drought. Islamabad is one of the successful cities that need to be followed by the other government from another city to improve disaster resilience.

Table 5. The land cover in Islamabad, Pakistan, from 2017 to 2023

	Year						
Land cover	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Water	0,6%	0,6%	0,7%	0,8%	0,7%	0,7%	0,7%
Trees	23,0%	23,0%	22,0%	25,0%	23,0%	22,0%	22,0%
Flooded Vegetation	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Crops	30,0%	36,0%	34,0%	33,0%	31,0%	27,0%	29,0%
Built Area	28,0%	28,0%	31,0%	32,0%	33,0%	35,0%	36,0%
Bare Ground	0,1%	0,1%	0,1%	0,1%	0,1%	0,2%	0,0%
Snow / Ice	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Clouds	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Rangeland	18,0%	12,0%	13,0%	9,0%	12,0%	15,0%	13,0%

4 Discussion

(Jackson & Decker Sparks, 2020) Climate change is worsening nowadays due to the greenhouse gas effect. It increases the earth's temperature, raises the sea level, and causes anomalies in the weather, either extremely droughty or rainy. The heatwave in Europe and China, worsened by climate change, brought prolonged rain to Pakistan from July to August 2022. With vulnerable ecosystems caused by deforestation in some areas, floods occur extremely and destroy everything that faces them. 1,739 people died, and 12,867 got injured. 2.1 million people were left homeless, and much infrastructure was destroyed, causing 15.2 billion USD in economic losses. Currently, the annual deforestation rate in the country is the highest in South Asia [3]. This deforestation, along with environmental degradation and climate change, has led to the accumulation of heat on the Earth's surface, as well as an increase in cyclones and floods [23].

Over the past century, Pakistan has experienced almost 25 cyclonic storms/tornadoes and around 38 floods [24]. Additionally, deforestation has contributed to higher levels of poverty, illiteracy, and unemployment, resulting in a weakened socio-economic capacity at the household and community levels [24].

The results show that Pakistan can keep its forest cover at 2%, which is a good accomplishment because it can achieve zero net deforestation. These accomplishments could have happened because of the successful program from the Ministry of Climate Change and Environmental Coordination, Government of Pakistan. They have done two successful programs: the Billion Tree Tsunami and the 10 Billion Tree Tsunami [25]. In 2014, The Billion Tree Tsunami was an afforestation initiative initiated by the Pakistan Tehreek-e-Insaf (PTI), government of Khyber Pakhtunkhwa, Pakistan, as a proactive reaction to the issue of global warming. Pakistan's Billion Tree Tsunami initiative successfully rehabilitates 350,000 hectares of forests and degraded land, exceeding its obligation under the Bonn Challenge. The project aims to enhance designated forests' ecosystems, privately owned waste, and farmlands. This will involve close association with communities and stakeholders to ensure their active involvement in the project by implementing promotional and extension services. The project was successfully finished in August 2017, surpassing the expected timeframe.

After the success of this program, the Ministry of Climate Change and Environmental Coordination launched a bigger project called 10 Billion Tree Tsunami in 2019, a four-year project with a total cost of 125.1843 billion. The project is being implemented throughout Pakistan by the Ministry of Climate Change and the Provincial and Territorial Forest and Wildlife administrations. The Prime Minister of Pakistan, Imran Khan, inaugurated the program on September 2, 2018, as part of the "Plant for Pakistan Day". The primary goal of the "Ten Billion Tree Tsunami Program" is to restore and enhance the Forest and Wildlife resources in Pakistan. This program aims to improve the conservation of the current Protected Areas, promote eco-tourism, engage local communities, and create green jobs [26].

This program was very good and was praised by the United Nations Environment Programme (UNEP), in words, “We are at a point in history where we need to act, and Pakistan is leading on this important effort.” World Economic Forum applauded adding 350,000 hectares of trees. Moreover, it congratulated Pakistan for reaching its target of a billion trees ahead of schedule. Pakistan exceeded its Bonn Challenge commitment; Khyber Pakhtunkhwa, a province in Pakistan, became the first international entity to complete the challenge the success of the Bonn Challenge, Head of the International Union for Conservation of Nature (IUCN)'s Inger Anderson dubbed the project “a true conservation success story.” Based on international appreciation, Saudi Arabia contacted the government of Pakistan to plant 10 billion trees in their country. However, the campaign sparked controversy due to allegations of PTI mismanagement and political manipulation.

Research on climate change communication highlights the importance of managing perceptions during such campaigns. Misinformation and misperceptions can damage future efforts to address climate change. A survey was conducted to understand young people's views on the Billion Tree Tsunami campaign. Interviews with 500 young people in the province of Khyber Pakhtunkhwa were conducted. The survey revealed that the campaign's politicization influenced youth perception. They had mixed feelings about it. According to them, the campaign motivated them to take action against climate change. The campaign had a strong media presence, and the ruling party, PTI, supported it with independent evidence. However, there was a limited effort to ensure a cross-sectional understanding of the campaign. Fig.2 shows the positive and negative effects of the Billion Trees Afforestation Project (BTAP) succession [27].

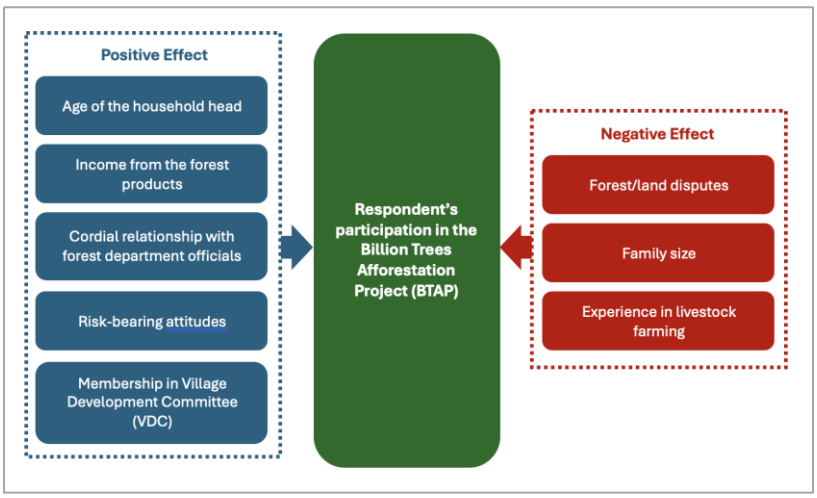

Fig. 2. The positive and negative effects of the succession of the Billion Trees Afforestation Project (BTAP).

Moreover, some philanthropy people in Pakistan plant forests on their private land, even though the area is relatively small compared to the state forest. Still, this is a good thing and needs to be supported by the government. Multi-stakeholder involvement will speed up the success of afforestation in Pakistan. The private company can help fund CSR for conducting the afforestation, while the community can help as the labor to plant and take care of the trees [19].

Based on the research results, it is known that more than half of the land in Pakistan is covered with Rangeland (Table 2). This means that the most suitable forest that can be planted easily is Savanna. Savanna is a type of forest that consists of a small number of trees and is mostly dominated by grasses, bushes, and shrubs. This ecosystem was formed due to the lack of water resources, which are most relevant to the conditions in Pakistan's land. Based on previous research [28], there are four best management strategies for achieving sustainable forest management in savannas:

1. Increase the community's knowledge of sustainable farming in savanna.
2. Providing a good fire management system
3. Making a good policy for managing the savanna resources
4. Enabling multistakeholder involvement

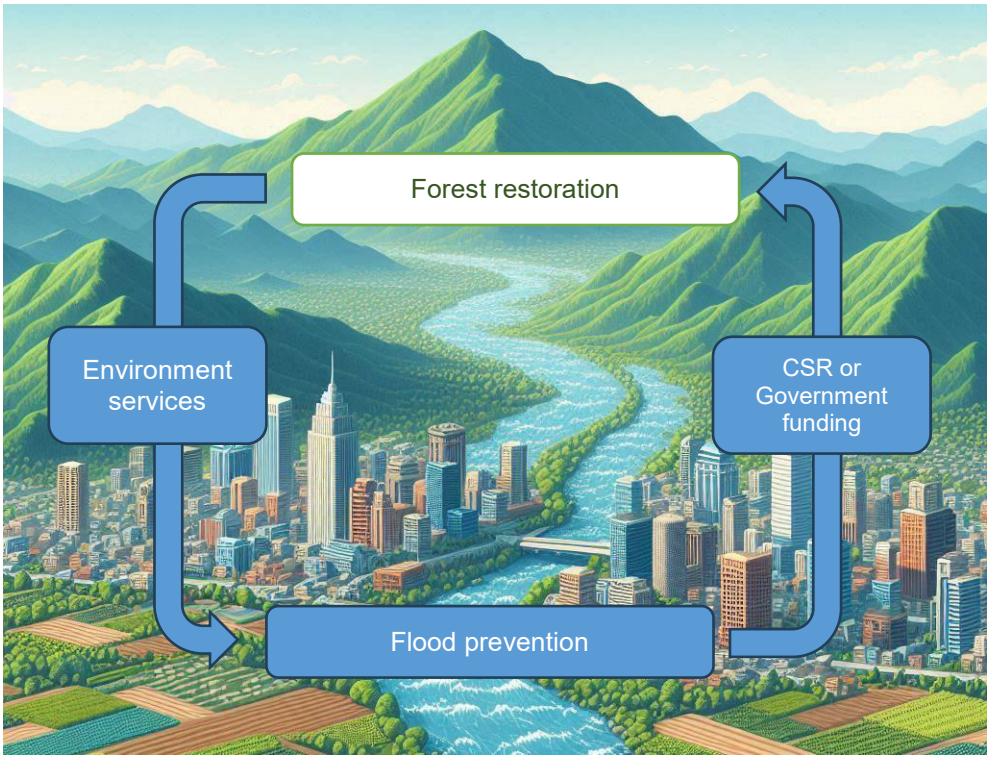

Fig. 3. Illustration of Payment for Environmental Services

Furthermore, the afforestation programs could also be funded through the Payment for Environmental Services scheme (Fig.3). This scheme focuses on prevention to avoid potential damages caused by disasters [29]. Compared to the economic loss caused by the flood in 2022, which was 15.2 billion USD, the cost of conducting the 10 billion tree

tsunami program is only 0.4 billion USD. Some money should be invested rather than waiting for the disaster and used to recover; it is better to use it for mitigation, such as continuing and enlarging the 10 billion Tree Tsunami program. Zero net deforestation is already a good accomplishment, but the forest cover of 2% is too small. With good communication and deliberation, multi-stakeholder involvement, and a supportive enabling policy, it can be possible to increase the forest cover in Pakistan, enhance environmental quality, and improve disaster resilience [19,30].

5 Conclusion

The devastating floods of 2022 in Pakistan killed 1,739 people and caused 15.2 billion USD in economic losses, underscoring the urgent need for proactive environmental management strategies. This study investigates land cover changes, focusing on forest cover, in Pakistan from 2017 to 2023, aiming to inform policy and mitigation efforts. High precipitation intensity from July to August 2022 exacerbated the impact of the floods, revealing the region's vulnerability. The analysis reveals a stark reality: Pakistan's forest cover is a mere 2%, highlighting the critical need for intervention. Protecting existing forest cover along with Government-led afforestation initiatives with the 10 Billion Trees Tsunami underway signals a proactive response, intending to bolster environmental resilience and reduce the susceptibility to natural disasters. Further afforestation programs with multi-stakeholder involvement and the Payment for Environmental Services (PES) scheme must be implemented to continue and expand the program.

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References

1. Ahmad, A.; Liu, Q.J.; Nizami, S.M.; Mannan, A.; Saeed, S. Carbon Emission from Deforestation, Forest Degradation and Wood Harvest in the Temperate Region of Hindukush Himalaya, Pakistan between 1994 and 2016. *Land use policy **2018**, 78, 781-790*
2. FAO *Global Forest Resources Assessment 2020*; 1st ed.; FAO, 2020
3. FAO *Global Forest Resources Assessment 2015*; 2nd ed.; FAO, 2016
4. Qamer, F.M.; Shehzad, K.; Abbas, S.; Murthy, M.S.R.; Xi, C.; Gilani, H.; Bajracharya, B. Mapping Deforestation and Forest Degradation Patterns in Western Himalaya, Pakistan. *Remote Sens (Basel)* **2016**, *8*
5. Yusuf, M. Legal and Institutional Dynamics of Forest Management in Pakistan. *McGill International Journal of Sustainable Development Law & Policy* **2009**, *5*, 45–71
6. Gupta, T.; Gupta, R.K.; Raina, K.K. Socio-Economic Factors Associated with Fuel Consumption Pattern in Rural Habitation of Jammu Region, Jammu & Kashmir. *Indian Journal of Forestry* **2009**, *32*, 387–390

7. Mariam Altaf Pakistan: Flood Damages and Economic Losses Over USD 30 Billion and Reconstruction Needs Over USD 16 Billion - New Assessment Available online: https://www.worldbank.org/en/news/press-release/2022/10/28/pakistan-flood-damages-and-economic-losses-over-usd-30-billion-and-reconstruction-needs-over-usd-16-billion-new-assessme (accessed on 8 May 2024).
8. Hong, C.C.; Huang, A.Y.; Hsu, H.H.; Tseng, W.L.; Lu, M.M.; Chang, C.C. Causes of 2022 Pakistan Flooding and Its Linkage with China and Europe Heatwaves. *NPJ Clim Atmos Sci* **2023**, *6*
9. Syartinilia; Condro, A.A.; Tsuyuki, S. Projected Impacts of Climate Change and Anthropogenic Effects on Habitat Distribution of Endangered Javan Hawk-Eagle in Indonesia. *Geography and Sustainability* **2024**, *5*, 241–250
10. Yin, J.; Gentine, P.; Zhou, S.; Sullivan, S.C.; Wang, R.; Zhang, Y.; Guo, S. Large Increase in Global Storm Runoff Extremes Driven by Climate and Anthropogenic Changes. *Nat Commun* **2018**, *9*
11. Ying, Y.Q.; Song, L.L.; Jacobs, D.F.; Mei, L.; Liu, P.; Jin, S.H.; Wu, J.S. Physiological Response to Drought Stress in Camptotheca Acuminata Seedlings from Two Provenances. *Front Plant Sci* **2015**, *6*, 1–8
12. Grimm, N.B.; Fisher, S.G. Responses of Arid-Land Streams to Changing Climate. In Proceedings of the Global Climate Change and Freshwater Ecosystems; Firth, P., Fisher, S.G., Eds.; Springer New York: New York, NY, 1992; pp. 211–233.
13. Jagodziński, A.M.; Zasada, M.; Bronisz, K.; Bronisz, A.; Bijak, S. Biomass Conversion and Expansion Factors for a Chronosequence of Young Naturally Regenerated Silver Birch (Betula Pendula Roth) Stands Growing on Post-Agricultural Sites. *For Ecol Manage* **2017**, *384*, 208–220
14. Bronisz, K.; Mehtätalo, L. Seemingly Unrelated Mixed-Effects Biomass Models for Young Silver Birch Stands on Post-Agricultural Lands. *Forests* **2020**, *11*
15. Bronisz, K. Modeling of the Tree and Stand Parameters Using Mixed-Effects Models. *Sylwan* **2019**, *163*, 564–575
16. Nurrochmat, N.A.; Purnomo, H.; Muhdin; Erbaugh, J.T. Developing Sustainable Models of Agroforest-Landscape in Bogor, Indonesia. *Biodiversitas* **2023**, *24*, 4324–4333
17. ESRI Sentinel-2 Land Cover Available online: https://livingatlas.arcgis.com/landcoverexplorer/#mapCenter=-77.53956%2C38.95146%2C11&mode=step&timeExtent=2017%2C2023&year=2023 (accessed on 15 June 2024)
18. Setiawan, Y.; Kustiyo, K.; Hudjimartsu, S.A.; Purwanto, J.; Rovani, R.; Tosiani, A.; Usman, A.B.; Kartika, T.; Indriasari, N.; Prasetyo, L.B.; et al. Evaluating Visible–Infrared Imaging Radiometer Suite Imagery for Developing Near-Real-Time Nationwide Vegetation Cover Monitoring in Indonesia. *Remote Sens (Basel)* **2024**, *16*
19. Nurrochmat, N.A.; Purwawangsa, H.; Mutaqin, F.; Ridwan, M.; Qanitha, M.; Mustakiman; Putra, S.A.; Nurkholid, Y.; Perdhana, R.D. Productive Carbon Forest: Agroforestry with High Economic Forest Commodities to Increase Carbon Stocks and Community Welfare in Garut Indonesia. In Proceedings of the IOP Conference Series: Earth and Environmental Science; Institute of Physics, 2024; Vol. 1315, pp. 1–10
20. The Government of Pakistan About Pakistan Available online: https://pakistan.gov.pk/
21. Hu, Y.; Raza, A.; Syed, N.R.; Acharki, S.; Ray, R.L.; Hussain, S.; Dehghanisanij, H.; Zubair, M.; Elbeltagi, A. Land Use/Land Cover Change Detection and NDVI

Estimation in Pakistan's Southern Punjab Province. *Sustainability (Switzerland)* **2023**, *15*

22. Nurrochmat, D.R.; Suryanto; Nurrochmat, N.A.; Tarigan, S.; Siregar, I.Z.; Rizki, D.L.Y.; Radjawali, I.; Sulistio, H. Indonesia's Options in Becoming a High-Income Country: Accelerating the Turning Point in Deforestation? *For Policy Econ* **2023**, *148*, 1–9
23. Jackson, B.; Decker Sparks, J.L. *Title: Ending Slavery by Decarbonisation? Exploring the Nexus of Modern Slavery, Deforestation, and Climate Change Action via REDD+*; 2020
24. Hamidi, A.R.; Zeng, Z.; Khan, M.A. Household Vulnerability to Floods and Cyclones in Khyber Pakhtunkhwa, Pakistan. *International Journal of Disaster Risk Reduction* **2020**, *46*, 101496
25. Goheer, M.A.; Fatima, L.; Farah, H.; Hassan, S.S.; Abbas, N. Assessment of Change in Forests Land, Carbon Stock and Carbon Emissions of KPK, Pakistan for Past Three Decades Using Geospatial Techniques. *Journal of Water and Climate Change* **2023**, *14*, 442–453
26. Kamal, A.; Yingjie, M.; Ali, A.; Significance, A.A. Of Billion Tree Tsunami Afforestation Project and Legal Developments in Forest Sector of Pakistan. *International Journal of Law and Society* **2018**, *1*, 157–165
27. Ashraf, U. *Country Report Participation and Exclusion in Mega Tree-Planting Projects A Case Study of the Ten Billion Tree Tsunami Programme, Pakistan Produced by IIED's Natural Resources Group*; 2022
28. Perdinan; Tjahjono, R.E.P.; Infrawan, D.Y.D.; Armanto, A.N.; Pratiwi, S.D.; Putra, E.I.; Yonvitner; Oktaviani, S.; Lestari, K.G.; Adi, R.F.; et al. Management Strategies of Tropical Savanna Ecosystem for Multiple Benefits of Community Livelihoods in Semiarid Region of Indonesia. *World Development Sustainability* **2024**, *4*
29. Dominicis, L.F. de; Lima, M. de F. de B.; Souza, Á.N. de; Joaquim, M.S.; Araújo, J.B.C.N.; Coelho Junior, L.M.; Ribeiro, J.F.; Santos, P.P. dos Payment for Environmental Services and the Financial Viability of Agroforestry Systems: An Integrated Analysis of Socio-Environmental Projects in the Descoberto Basin—Federal District. *Forests* **2023**, *14*
30. Erbaugh, J.T.; Chang, C.H.; Masuda, Y.J.; Ribot, J. Communication and Deliberation for Environmental Governance. *Annu Rev Environ Resour* **2024**