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Research Article

Population dynamics of *Monothecha buxifolia* in sub-tropical broad leaf evergreen forest of District Mohmand, KPK

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ABSTRACT

The population dynamics of *Monothecha buxifolia*, commonly known as Gurgura, were investigated in the sub-tropical broad-leaved evergreen forests of district Mohmand, Khyber Pakhtunkhwa (KPK). This study aimed to assess the economic and medicinal potential and to determine the loss due to deforestation of *M. buxifolia* in Sub-tropical Broad leaf Evergreen Forest. The economic evaluation focuses on the commercial prospects of *M. buxifolia*. This study analyzed *M. buxifolia* as an oil-rich fruit for potential industrial use. This study gauges the feasibility of sustainable economic ventures associated with this species by examining market trends, supply chains, and demand dynamics. Simultaneously, the study delves into the medicinal potential of *M. buxifolia*, investigating its traditional uses and modern medical applications. Traditional practices also reveal that *M. buxifolia* played a significant role in veterinary medicine for anti-helminthic applications. The plant's various parts, including leaves, bark, and fruits, are traditionally believed to possess therapeutic properties such as antioxidants. Market surveys and value chain analysis were done in the study area to meet the objectives of phytochemical analysis. The satellite data for deforestation was downloaded from ArcGIS software. To obtain information about topographic parameters like slope and elevation, (DEM) Digital Elevation model was used. The key findings are *M. buxifolia* provides a reliable source of income and cash flow for local communities. The fresh fruit contains citric acid, ascorbic acid and sugar. This suggests that the fruit has a relatively high concentration of sugars, which could contribute to its sweetness and energy content.

Keywords: Population dynamics; deforestation; phytochemical analysis; ArcGIS; digital elevation model.



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INTRODUCTION

Monothecha buxifolia commonly known as Gurgura belongs to the genus *Monothecha* and the family Sapotaceae. This is one of the important broadleaved forest species. It is thoroughly distributed primarily in Pakistan and Afghanistan's border regions (Zahoor et al., 2019). This species is native to various regions across Asia, including parts of India, Nepal, Bhutan, Myanmar, and China. It is generally found in subtropical and temperate forested areas, often growing in the understory of larger tree species. The plant prefers well-drained soils and can tolerate a range of ecological conditions. This species' fruit has laxative and digestive qualities and is generally used in urinary tract infections. Despite the existence of other useful plant species, *M. buxifolia* is most frequently used in Northwest Pakistan. This may be a result of its great socioeconomic significance in the culture that is now in place (Ali et al., 2023). In traditional medicine, several parts of *M. buxifolia*, including its leaves and bark, have been used to relieve symptoms of rheumatism and arthritis. The plant is believed to have anti-inflammatory qualities that may help reduce pain and

swelling associated with these conditions (Ullah et al., 2013). Comparatively to some other species *M. buxifolia* is the most preferred in mountainous areas. It is generally used as fuel, fodder, and small timber, and in particular, because of its thorny type nature, it is used as a fence around farmed areas. This species produces fruits that provide locals with a source of income (Khan, Amjad & Arshad 2010). The sub-tropical broadleaf forests in Mohmand district hold significant ecological value due to their biodiversity, contribution to local livelihoods, and role in watershed management. They are also culturally significant to the indigenous communities living in the region. *M. buxifolia* has economic value for the locals in harsh, mountainous regions. In some regions, this tree species holds cultural importance and is used in services and ceremonies. This can include offerings, decorations, or other cultural practices that may have economic implications for local artisans and communities (Ali et al., 2022). The traditional horticultural and agronomic operations are typically weak in the distant mountain settlements. As a result of heavy anthropogenic pressure brought on by many uses, this tree species has seen a rapid decline in both its population size and distributional range during the past few decades (Ali et al., 2023). This species' seeds contain oil that can be extracted and possibly used for a variety of things. If the oil is deemed to be secure and fit for ingestion, it might be utilized in soaps, cosmetics, or even as cooking oil (Athar et al., 2005). *M. buxifolia* yields a firm, solid wood that might be utilized for carving, building, or crafting tasks. The tree is not well recognized for its timber, and there may be variations in the quality and availability of the wood (Wani et al., 2022). Only plants are used by around 80% of the world's population for health and healing. However, reliance on medical procedures and pharmaceuticals is increasingly common in developed nations. However, in recent years they have begun to pay more attention to natural supplements. People's interest in herbs is driven by their concern for the negative consequences of medications made from synthetic components (Khalil et al., 2007). According to reports, this tree species is either pure forest or in the form of mixed forest with broad-leaved tree species i.e., *Dalbergia sissoo*, *Acacia nilotica*, *Ziziphus mauritiana*, *Dalbergia latifolia*, and *Eucalyptus globulus* (Wahab et al., 2010). The Hindukush Mountains in Pakistan are regarded as a center of biodiversity, contributing 2400 species to the country's total 6000 species that have been recorded (Ali et al., 2022). According to environmentalists, ecologists, and foresters, the principal contributors are predominantly coniferous and hardwood species, both of which are quickly declining because of anthropogenic influences (Jones et al., 2022). Very little attention was paid to the description of species composition, dominance, diversity, richness, and regeneration ability in the Monotheca forest. This research study will provide valuable insights into the sustainable management of *M. buxifolia* forests. By highlighting the economic and medicinal benefits, the study aims to promote the conservation of this species, encouraging local communities and policymakers to adopt practices that ensure its preservation. Furthermore, the findings on deforestation will help in developing strategies to mitigate forest loss and promote reforestation efforts. For the first objective, a mixed-methods approach is adopted. Data is collected from various stakeholders, including local inhabitants, market traders, and traditional healers. Both qualitative and quantitative data are analyzed to provide a holistic view of the economic and medicinal potential of *M. buxifolia*. To achieve the second objective, remote sensing data is utilized. The research study employs Landsat 7 and 8 imageries, downloaded from the USGS website, and the supervised Maximum Likelihood Classification (MLC) algorithm for spectral classification. This research work basically focused to assess the economic and medicinal potential of *M. buxifolia* in sub-tropical broad leaf evergreen forest and to determine the loss due to deforestation. Accuracy assessments are conducted to validate the findings, ensuring reliable results. The objective of the present instigation is to determine the economic and medicinal potential and loss due to the deforestation of the *M. buxifolia* in forest in district Mohmand to help in the conservation of this commercially and ecologically important forest species.

MATERIALS AND METHODS

The study site is located in Pakistan's northwest side, near the border with Afghanistan (Figure a). It is part of the larger Khyber Pakhtunkhwa province and falls within the region known for its diverse and unique ecological features. The study area in Mohmand District features a diverse and captivating landscape, encompassing a wide range of topographical features. This includes rugged mountain ranges, undulating hills, and picturesque valleys. The study area encounters a wide range of temperatures. Summers can be hot, with maximum temperatures often exceeding 30°C (86°F), while winters can be cool, with temperatures dropping below freezing in some parts. The total population of the area is 502306, located at 34, 10° to 34 43° N-latitudes, 70 58° to 71 42° E-longitude. The covered area is 2297 square kilometers. The sub-tropical broadleaf forests in Mohmand District are characterized by a rich diversity of plant species. Besides *M. buxifolia*, other prominent tree species may include oak, pine, and various deciduous trees. The

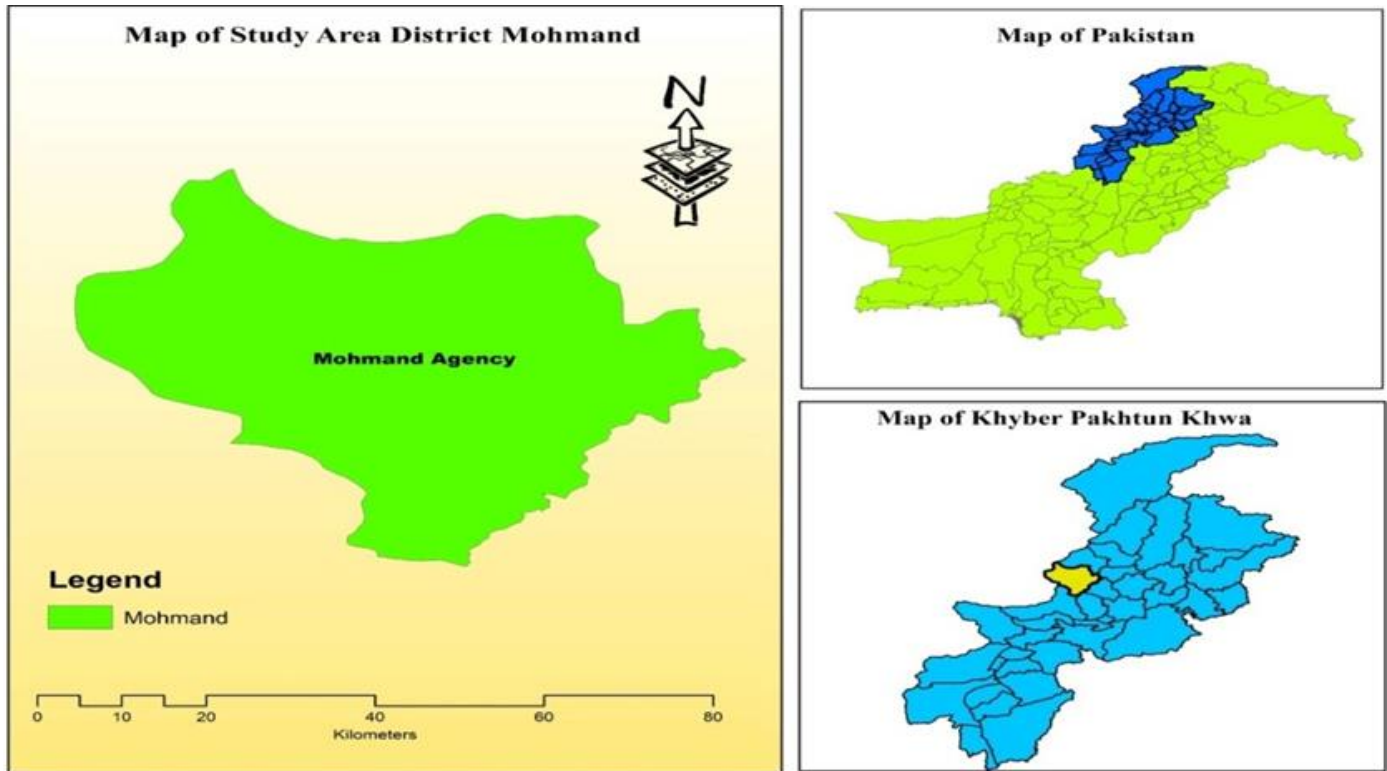


Figure a. Map of the district Mohmand (study area).

region supports a diverse range of flora and fauna. Agriculture, forestry, and urban development may be prominent land uses in the study area.

Data Collection

To assess the economic potential of *M. buxifolia* (locally known as gurgura), data was collected from 40 respondents across upper and lower Mohmand, Prang Ghar, Ambar Utmankhel, Safi, Haleemzai and Baizai tehsils of District Mohmand. The respondents included individuals of varying ages and genders. This data collection occurred during the peak fruiting season of June and July, which provided a critical period for observing and analyzing the species' commercial viability. Data was collected through questionnaires and surveys.

Questionnaires and Surveys

Structured questionnaires were designed to gather quantitative and qualitative data from the local community. The surveys were administered through face-to-face interviews. Observations and informal interviews were conducted in local markets to understand the commercial value and trade practices associated with *M. buxifolia*.

Stakeholder Engagement

Key stakeholders, including local inhabitants, traders, and market vendors, were consulted to gain insights into the economic significance of *M. buxifolia*. Information was gathered on the following aspects. The role of *M. buxifolia* as a source of income for local communities. Current market prices for *M. buxifolia* fruits, both fresh and dried, range from 600-800 rupees per kg (2024 data). Uses of *M. buxifolia* wood for fuel, furniture, fencing, and as fodder for livestock.

Extraction of Oil

The oil was extracted from the seeds of *M. buxifolia* using a standardized extraction procedure. Fresh fruits were collected, and seeds were separated. The seeds were subjected to oil extraction through a mechanical press. The extracted oil was then analyzed in the central laboratory of the Research and Development Directorate, Khyber Pakhtunkhwa Forest Department.

Analysis of Fruit Composition

The moisture content, citric acid, ascorbic acid, and total sugars of the fresh fruit were determined using established analytical techniques. The fresh fruit was evaluated for moisture content using a moisture analyzer, while citric acid and ascorbic acid were quantified using high-performance liquid chromatography (HPLC). Total sugars were measured using a colorimetric assay.

Seed Composition Analysis

The seed's oil content, total carbohydrates, protein, and ash were analyzed. Oil content was determined by Soxhlet extraction, and the results were calculated on both a wet and dry mass basis. Total carbohydrates were quantified using the phenol-sulfuric acid method, protein content was measured using the Kjeldahl method, and ash content was determined by incineration at 550°C.

Oil Characterization

The extracted oil was characterized by its peroxide value and saponification value. The peroxide value, indicative of the oil's oxidative stability, was measured using the iodometric method. The saponification value, which reflects the fatty acid composition, was determined according to the standard titration method.

Satellite Imagery

Landsat 7 and Landsat 8 satellite images were used for this study. These images were obtained from the USGS website (<http://glovis.usgs.gov/>) for the years 2004 and 2024. Pre-monsoon season images were selected to minimize cloud cover interference. Images were selected based on the minimal cloud cover and high-quality resolution to ensure accurate classification.

Supervised Classification

A Supervised Maximum Likelihood Classification (MLC) algorithm was employed to classify the spectral data of the Landsat images. This method was chosen due to its effectiveness in handling remote sensing data and distinguishing between different land cover types. The primary land cover class of interest was *M. buxifolia* forest. The classification process involved training the MLC algorithm with ground truth data collected from the imagery.

RESULTS AND DISCUSSION

Economic Potential of *M. buxifolia*

Figure 1 shows various economic uses of *M. buxifolia*. According to the findings of the study, this is a significant economic resource for local mountain inhabitants, particularly in areas with rough terrain where conventional agriculture is limited. The key findings are *M. buxifolia* provides a reliable source of income and cash flow for local communities. The fruit is highly valued and sold at 600-800 rupees per kg in the market. The fruit, known for its delicious taste in both fresh and dry forms, has a steady demand in local markets. The wood of *M. buxifolia* is primarily used for fuel due to its efficient burning properties, even when not fully dried. Its bushy nature and numerous root suckers make it a preferred fuelwood tree. Large and older trees are occasionally used for making light furniture and doors. The tree also serves as a fodder source for camels, sheep, and goats. Its thorny nature makes it an effective natural fence around cultivated fields and fruit gardens. Local communities perceive *M. buxifolia* as a vital component of their livelihood. Its multifaceted uses, from providing fuelwood to serving as a food source and a material for light furniture, highlight its economic and practical importance in the region.

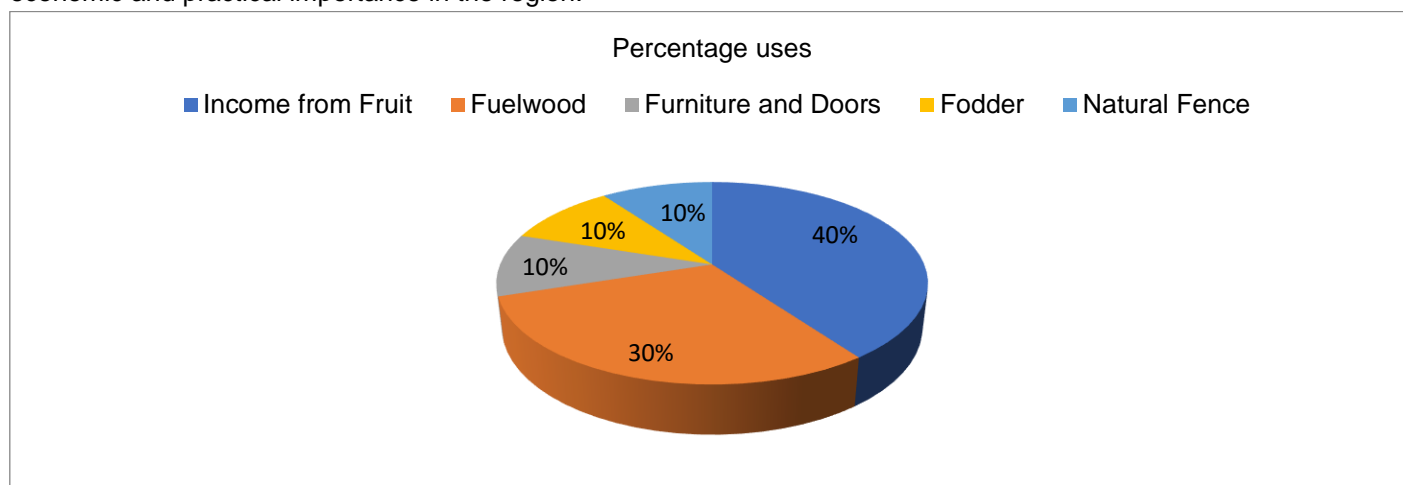


Figure 1. Economic Uses of *M. buxifolia*.

Medicinal Potential of *M. buxifolia*

Table 1 is depicting the analysis of the fresh fruit of *M. buxifolia* which shows that the fresh fruit contains 54.8% moisture. This high moisture content indicates that the fruit is relatively hydrous, which may influence its storage and processing characteristics. The citric acid content was determined to be 0.2%. This is relatively low, suggesting limited

acidity in the fruit, which might impact its taste and preservation properties. Ascorbic acid (vitamin C) was found at a concentration of 0.05%. This low level of ascorbic acid indicates that the fruit has minimal vitamin C content. The total sugar content in the fresh fruit is 23.77%. This suggests that the fruit has a relatively high sugar concentration, which could contribute to its sweetness and energy content.

Table 1. Proximate analysis of *M. buxifolia* fruit.

Component	Value
Moisture Content	54.8%
Citric Acid	0.2%
Ascorbic Acid	0.05%
Total Sugars	23.77%

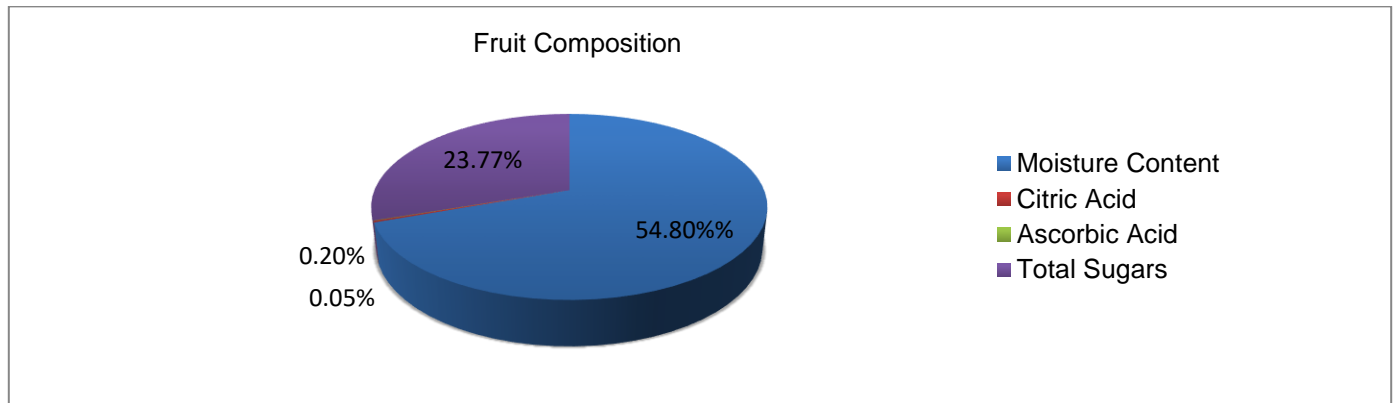


Figure 2. Composition of fresh fruit.

Composition of Seed

Figure 3 shows the percentage composition of seed, which constitutes approximately 60% of the fruit, was analyzed and the compositions were recorded. The seed contains 16.9% oil on a wet mass basis, and 17.7% oil on a dry mass basis. This indicates that a significant portion of the seed’s mass is made up of oil, which is a key indicator of its potential nutritional and industrial value. The seed also contains 66.5% total carbohydrates on a wet mass basis and 61.8% on a dry mass basis. This high carbohydrate content suggests that the seed could be a substantial source of energy. The protein content in the seed is 10.8% on a wet mass basis and 11.3% on a dry mass basis. This indicates that the seed has a notable amount of protein, which might be useful in dietary and nutritional applications. The seed contains 1.3% ash on a wet mass basis and 1.4% on a dry mass basis. Ash content is indicative of the mineral content of the seed, which plays a role in its overall nutritional profile. The pie chart below displays the relative proportions of oil, total carbohydrates, protein, and ash content in the seed of *M. buxifolia*.

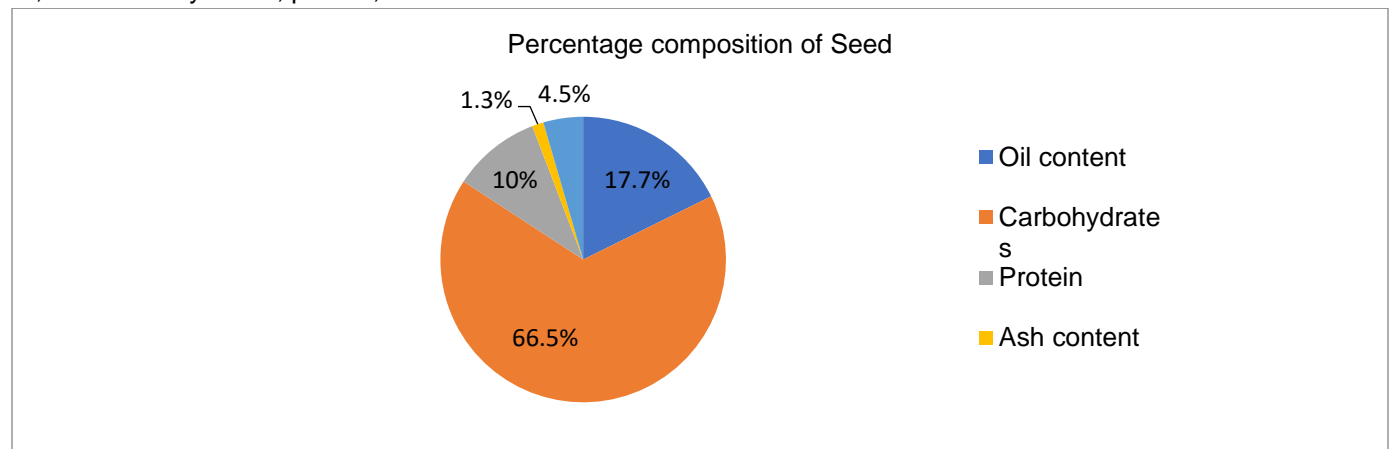


Figure 3. Percentage composition of seed.

Oil Characteristics

The extracted oil from the seed was analyzed for its quality parameters. The peroxide value of the oil is 61.9 meq/kg. This value indicates the extent of lipid oxidation and can be used to assess the freshness and stability of the oil. A high peroxide value suggests that the oil may be prone to oxidative degradation. The saponification value of the oil is 188.8 mg KOH/g. This value reflects the average molecular weight of the fatty acids in the oil and provides insight into its potential uses in soap-making and other applications.

Traditional Medicinal Uses

Based on data collected from local communities across seven tehsils of the Mohmand District through questionnaires and surveys, several traditional medicinal applications of *M. buxifolia* have been identified. According to respondents, the oil extracted from the seeds of *M. buxifolia* was historically employed as an analgesic. This oil was topically applied to areas of the body affected by pain. The use of seed oil for pain relief underscores its potential analgesic properties, which warrant further investigation through pharmacological studies. Historical practices also reveal that *Monotheca buxifolia* played a significant role in veterinary medicine for anti-helminthic applications. Specifically, juice extracted from the leaves of the plant was administered orally to domestic animals afflicted with parasitic worm infestations. This traditional remedy highlights the potential anthelmintic properties of the plant and suggests its historical relevance in managing gastrointestinal parasitism in livestock.

Land Cover Classification

The classification results revealed that the *M. buxifolia* forest area increased from 1704.4 hectares in 2004 to 2294.46 hectares in 2024. This represents an increase of 590.0 hectares over two decades, suggesting an expansion rather than a loss of forest area. The increase in forest area could be attributed to several factors, including effective forest management practices or natural regeneration. Further investigation into these factors may provide a deeper understanding of the underlying causes.

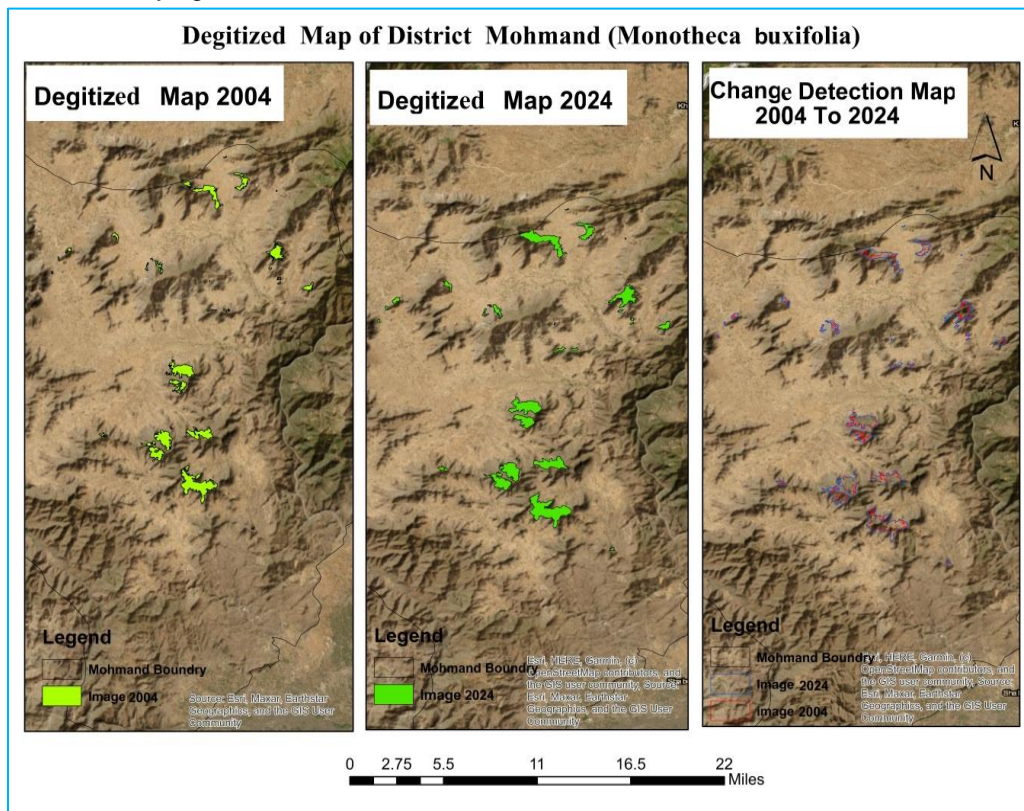


Figure 4. Digitized map of 2004 and 2024 and their change map.

Image 2004		Image 2024		
Name of site	Area(ha)	Name of site	Area(ha)	Change(2004-2024)

Sheikhali baba	172.1	Sheikhali baba	175	+2.9
Halimzai.pindiali	407.2	Halimzai.pindiali	480	+72.8
Bar molyan	1.5	Bar molyan	3.9	+2.4
Nahaqi top	136.7	Nahaqi top	175	+38.3
Munda khel	151.5	Munda khel	197	+45.5
Tora garai	198.8	Tora garai	251	+52.2
Sado kor	93.1	Sado kor	129	+35.9
Zinawar china	12.6	Zinawar china	21.5	+8.9
Garang area	2.7	Garang area	7.8	+5.2
Kohi e mor1	131.4	Kohi e mor1	217	+85.6
Kohi mor 2	3.8	Kohi e mor 2	6.1	+2.3
Drawo1	4.6	Drawo1	5.8	+1.2
Drawo 2	3.1	Drawo 2	4.8	+1.7
Olai	36.2	Olai	46.9	+10.7
Sagi	22.0	Sagi	30.4	+8.4
Sheikh ali 2	2.1	Sheikh ali 2	5.26	+3.2
Lakaro	3.1	Lakaro	6.5	+3.4
Zyarat	14.2	Zyarat	24.8	+10.6
Musa kor	5.6	Musa kor	9.4	+3.8
Musa kor1	0.7	Musa kor 1	2.2	+1.5
Musa kor 2	1.9	Musa kor 2	4.8	+2.9
Musa kor 3	32.2	Musa kor 3	44.3	+12.1
Ambar utman	170.5	Ambar utman	304	+133.5
Ambar utman 1	7.4	Ambar utman 1	12.5	+5.0
Ambar utman 2	0.8	Ambar utman 2	0.9	+0.1
Gumbati site	0.3	Gumbati site	1.4	+1.1
Gumbati site1	4.8	Gumbati site1	21.5	+16.7
Ambar site 3	82.5	Gumbati site 3	104	+21.5
Sheikhano	1.0	Sheikhano	1.7	+0.7
Total area 2004	1704.4	Total area 2024	2294.46	+590.0

Table 2. Sites where plots were taken.

Statistical Analysis

Post-classification comparison was used to detect changes in *M. buxifolia* cover between 2004 and 2024. The areas of forest cover for each year were calculated and compared. Descriptive statistics, including mean and standard deviation, were used to summarize the change in forest area. A linear regression model was applied to analyze the trend over time, with the year as the independent variable and forest cover as the dependent variable.

Logistic Regression Model

To assess the economic impact of *M. buxifolia*, logistic regression was employed. This model examined the relationship between continuous independent variables (such as income derived from forest resources) and a binary outcome variable (presence or absence of income from the forest). The logistic regression model was formulated as follows:

$$\text{Logit}(\pi) = \ln(\pi/1-\pi) = \beta_0 + \beta^1 X^1_i + \dots + \beta_j X^j_i \quad (1)$$

where (p_i) represents the probability of household (i) generating income from the forest, and (X_{ji}) are the independent variables for household (i) .

The present study aimed to assess the economic and medicinal potential of *M. buxifolia* in the Sub-tropical Broad-leaved Evergreen Forest and to determine the loss due to deforestation of *M. buxifolia* in the forest. The key findings provide valuable insights into the significance of *M. buxifolia* as a resource for local communities and the changes in its forest area over two decades. Ali et al. (2022) combined the views of local individuals through a questionnaire. Their result indicates that *M. buxifolia* tree species provided a variety of ecosystem services to the local communities. The local environment has been seriously disrupted by illegal logging of the species for almost a decade, and war and terror in this region are exacerbating the problem. Ever-increasing overexploitation has caused the species' population size to rapidly fall as a result of numerous uses, and local communities as a result lose associated ecosystem services. The population density of plant species is severely impacted by anthropogenic-induced disturbances and environmental fluctuations that go beyond the threshold of toleration. *M. buxifolia* emerges as a significant economic resource for local mountain inhabitants, particularly in areas with rough terrain where conventional agriculture is limited. The fruit's market value, ranging from 600-800 rupees per kg, highlights its importance as a reliable source of income and cash flow for local communities. Pfaff et al. (1999) illustrate that the socio-economic impacts of deforestation are equally significant. Local communities suffer from the loss of income and resources derived from *M. buxifolia*. The reduction in availability of its products affects the livelihoods of many families in District Mohmand. The ecological consequences of deforestation are profound. The loss of *M. buxifolia* forests leads to soil erosion, reduced biodiversity, and altered microclimates. The degradation of these forests impacts the overall health of the ecosystem. The steady demand for the fruit, known for its delicious taste in both fresh and dry forms, underscores its economic viability. Additionally, the wood of *M. buxifolia* is primarily used for fuel due to its efficient burning properties, even when not fully dried. This attribute, coupled with the tree's bushy nature and numerous root suckers, makes it a preferred fuelwood tree. Large and older trees are occasionally utilized for making light furniture and doors, further adding to their economic value. The tree's role as a fodder source for camels, sheep, and goats, and its effectiveness as a natural fence around cultivated fields and fruit gardens, reinforce its multifaceted importance to local communities. The analysis of the fresh fruit of *M. buxifolia* revealed a high moisture content (54.8%), indicating its relatively hydrous nature, which may influence its storage and processing characteristics. The citric acid content was found to be 0.2%, suggesting limited acidity in the fruit. Ascorbic acid (vitamin C) was present at a concentration of 0.05%, indicating minimal vitamin C content. However, the total sugar content in the fresh fruit was 23.77%, highlighting its relatively high sugar concentration, which could contribute to its sweetness and energy content. These findings suggest that while *M. buxifolia* may not be a significant source of vitamin C, its high sugar content makes it a valuable source of energy for local communities. Contrary to the initial hypothesis, the classification results revealed that the *M. buxifolia* forest area increased from 1704.4 hectares in 2004 to 2294.46 hectares in 2024. This represents an increase of 590.0 hectares over two decades, suggesting an expansion rather than a loss of forest area. Akhtar et al. (2021) conducted a research study in which they found that deforestation of *M. buxifolia* forests is especially problematic as it exacerbates the vulnerability of local ecosystems to climate change, further threatening the sustainability of these forests and the livelihoods of communities' dependent on them. This increase could be attributed to several factors, including effective forest management practices, natural regeneration, or a combination of both. The expansion of the *M. buxifolia* forest area highlights the success of conservation efforts and the tree's adaptability to the local environment. However, further investigation into the underlying causes of this expansion is warranted to provide a deeper understanding of the factors driving this positive trend. Chakravarty et al. (2012) conducted a research study in which they found that the primary drivers of deforestation in the region include agricultural expansion, overgrazing, illegal logging, and infrastructure development. These activities lead to habitat loss and fragmentation, reducing the availability of suitable habitats for *M. buxifolia*. The conversion of forest land into agricultural fields and settlements disrupts the natural environment, making it difficult for the species to regenerate and thrive. Overgrazing by livestock further exacerbates the problem by damaging young saplings and preventing natural forest regeneration.

CONCLUSION

The study's findings underscore the economic and practical importance of *M. buxifolia* to local mountain inhabitants. The fruit's market value and steady demand, coupled with the wood's utility for fuel and light furniture, highlight its significant economic potential. Additionally, the tree's role as a fodder source and natural fence further emphasizes its multifaceted contributions to local livelihoods. The medicinal analysis of the fresh fruit indicates that while it may not

be a significant source of vitamin C, its high sugar content makes it a valuable energy source. The high moisture content suggests considerations for storage and processing, and the low citric acid content impacts its taste and preservation properties. Contrary to concerns about deforestation, the *M. buxifolia* forest area has expanded over the past two decades. This increase reflects effective forest management and natural regeneration processes. The positive trend in forest area expansion highlights the potential for sustainable management practices to support both conservation and local economic needs. In conclusion, *M. buxifolia* plays a vital role in the economic and practical lives of local communities, and its forest area is increasing rather than declining. Continued research and monitoring are essential to sustain and enhance the benefits derived from this important resource while ensuring its long-term conservation.

AUTHOR'S CONTRIBUTION

Ittehad Khan conducted the research, carried out data analysis, wrote the manuscript; Sabeeqa Usman Malik supervised the research and assisted in data collection, data analysis and writing the manuscript, assisted in data analysis; Saeed Gulzar supervised the research; Rashid Ahmed proofread and improved the manuscript; Sari Ullah Proofread and improved the manuscript.

FUNDING

The study was self-funded.

AVAILABILITY OF DATA AND MATERIAL

Data is available and will be furnished on demand.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All Authors have consented to participate in the publication.

CONSENT FOR PUBLICATION

All Authors have consented to participate in the publication.

CONFLICT OF INTERESTS

The authors have no conflict of interest.

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