A tentative sustainable management plan for Annapurna Conservation Area (ACA) based on evaluations of existing optimal management schemes in mountainous national parks and methodological analysis

Qiao Jiang

International Division, Beijing No.2 Middle School, Beijing, 100025, The People's Republic of China

*aoaotiantian@gmail.com

Abstract. Synthesizing a sustainable management scheme for a mountainous national park or alpine conservation zone involves analyzing existing and optimal strategies and proposing newborn methods adaptive to the given region. While present methods can be extracted from a variety of reserves located in different terrestrial biomes, merging innovative schemes with the status quo of the targeted alpine area proves salient. Offering one of the most extraordinary scenery and adventure experiences out there, Annapurna Conservation Area (ACA) in northwest Nepal hosts paramount numbers of tourists annually. However, due to the harshness of the local environment, deficiency in social productivity, and absence of a well-managed tourism industry, the ACA suffers from turbulence in economic growth, degradation of natural resources, and destruction of regional ecosystems. Here we present a tentative management plan for the Annapurna Conservation Area, created by combining existing schemes and specialized alternative methods suited for the ACA, enhancing its revenue while decreasing the rate of resource exploitation

Keywords: Nepal; management plan; mountain; tracking trails; national parks.

1 Introduction

This section will give an overview of the mountain tourism industry under current social and economic conditions, and with it, existing and harmful environmental impacts. Proving urgency and the need for further research is the main goal of the following paragraphs.

1.1 Mountain tourism and its significance

Mountaineering and trekking are major tourism activities in mountain areas that have helped to uplift the livelihood of local people. Tourism generates employment for youths as mountain guides and porters and helps in generating income for their living

Z. Wang et al. (eds.), *Proceedings of the 2023 2nd International Conference on Public Service, Economic Management and Sustainable Development (PESD 2023)*, Advances in Economics, Business and Management Research 273,
https://doi.org/10.2991/978-94-6463-344-3_51

[1]. Trekking and mountaineering in higher altitudes is the main source of revenue collection for local and national authorities occupying land near tall ranges [2]. About 10% of Gross Development Products (GDP) was spent on tourism in the world and this revenue has a great impact on the livelihood of developing economies. It increases the income of park management and enhances the economy of nearby gateway communities [3].

Due to its extraordinary scenery created by the continuing interactions of landscapes and the environment, the Nepalese Himalayas has been heavily altered by human activities, especially during the past 20 to 30 years with the substantial growth of mountaineering, trekking, and adventure tourism to remote mountain regions (Byers, 2005).

1.2 Overview of mountain tourism in Nepal

The 21st-century mountain tourism industry in the Nepalese Himalayas has been able to satisfy the desires of the majority who hope to seek outdoor leisure in remote alpine terrains, either for purposes of pursuing recreation, relaxation, and pleasure, or making use of the commercial provision of services. With exponential growth in adventure tourism, tourists are visiting destinations previously rarely exploited by the public between 2010 and 2014; the adventure tourism industry grew by 195%. Adventure travel is rapidly becoming mainstream. The international adventure tourism market is likely to grow at a compound annual growth rate of 45.99% during the period 2016-2020 (Upadhayaya, 2018). Sustainable development to protect local environments as well as promote adventure tourism appears to be urgently important by the hour.

Having the biggest alpine tourism industry in the world, Nepal has a mean value of nearly 600,000 tourists arriving annually [4]. International arrivals peaked in 2019 with more than 1.17 million people touching down and should have continued to increase exponentially throughout the following years if not for the Covid-19 outbreak in early 2020 that drastically minimized arrivals to less than 200,000 arrivals.

From Figure 1, Profits of Nepalese tourism should also be taken into serious consideration. Post Covid-19, the tourism economy has shown an upward trend in income, with revenues of 801 million USD, 740 million USD, 712 million USD, 498 million USD and 509 million USD from 2019 to 2015.

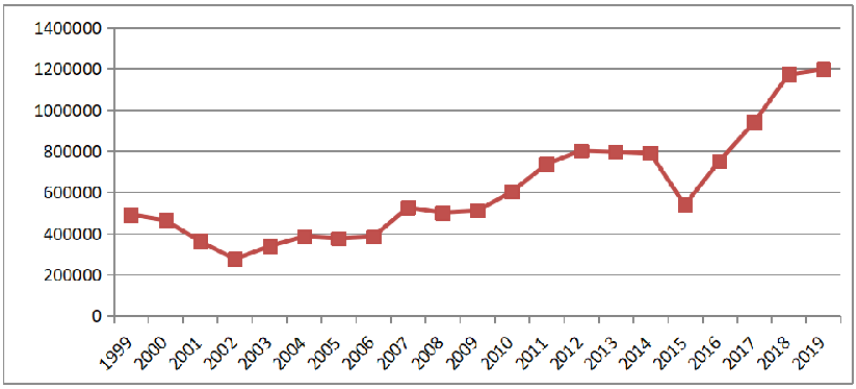


Fig. 1. Number of visitors arriving in Nepal internationally between 1999-2019 [5]. (Reason of drop in 2015 was the Nepalese Earthquake magnitude 8.1)

1.3 Environmental Impacts of Mountain Tourism

The environmental impact of tourism is particularly critical in mountain regions [6]. Several conditions make them highly vulnerable to ecological damage, such as environmental fragility and tourism seasonality. High-altitude ecosystems are inherently fragile and characterized by low resiliency, and therefore they are particularly susceptible to human interference, such as soil and vegetation trampling, disturbance to native wildlife, and waste dumping [7]. High-altitude recreation sites are characterized by extreme seasonality because accessibility and favourable climatic conditions are restricted to the short summer season. Consequently, human-induced disturbances in the environment are concentrated in this period, which is also the peak season for several biological processes, such as mating, vegetation growth, migration, spawning, etc.

Trekking, the most popular recreational activity in these mountains, defined as vigorous and long walks on countryside footpaths and trails, can also bring devastating consequences to alpine ecosystems [8]. Typical impacts caused by trekking are trail widening and incision, multiple treads, muddiness, soil erosion and compaction [9]. Biological impacts include vegetation trampling and degradation (e.g., root exposure), forest thinning (e.g., use of firewood by campers), decrease in biodiversity (e.g., loss of fragile species), wildlife disturbance, habitat fragmentation, and introduction of exotic species [10].

1.4 The Urgency of Sustainable Solutions

Mountains host biodiversity that is critical to humankind and to achieving a sustainable future in mountains and beyond. Yet, human pressure on mountains (e.g., through land-use change and unsustainable exploitation of mountain resources) is growing, and mountain ecosystems are increasingly degraded. Concomitantly, we are rapidly losing mountain biodiversity and with it the ability to provide water, safety, and food for communities in mountains and vast lowland areas [11]. Interpreting this message and

the environmental impacts stated in the previous section, a conclusion can be made: if we do not act with enough urgency and harmony to deal with these existing problems by continuing to strive for sustainable actions, the damage done to our mountains will be inevitably irreversible (un.org).

Widening down, sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs [12]. Sustainable development has continued to evolve as that of protecting the world's resources while its true agenda is to control the world's resources. The essence of this form of development is a stable relationship between human activities and the natural world, which does not diminish the prospects for future generations to enjoy a quality of life at least as good as our own [13]. Henceforth, the combination of well-structured sustainable initiatives along with a deep sense of urgency from each individual proves to be the dominating path to a brighter future [14].

1.5 Research Gaps

Currently, a lack of research endeavor into constructing sustainable trekking tracks is the biggest problem existing in Nepal's Himalayan tracks. With nearly 1.2 million people arriving in this South Asia nation pre Covid-19, it is hard to imagine what sort of detrimental effect tourism will have on the environmental well-being of local areas, especially in the absence of a well-developed trekking trail [15]. In this paper, we will be contrasting various existing management plans of various popular conservation zones globally, and synthesizing them into an optimal scheme that will match the needs of Annapurna Conservation Area (ACA).

1.6 Goals for this paper

1). Create a management plan for trekking tracks in alpine ecosystems which benefits economically, socially, and ecologically.

Annapurna National Park is a popular trekking destination in Nepal, attracting a large number of tourists every year. To create a management plan for trekking tracks in the alpine ecosystem of Annapurna National Park, it is necessary to consider the economic, social, and ecological impacts of tourism. The management plan should aim to generate economic benefits for the local community while minimizing the negative impacts on the environment. For instance, the plan may include measures such as promoting ecotourism, encouraging responsible trekking practices, providing alternative livelihood options for local communities, and regulating the number of tourists and trekking trails to reduce the ecological impact.

2). Demonstrate how a suitable and sustainable management plan for alpine tourism destinations should be analyzed and evaluated.

To evaluate a sustainable management plan for Annapurna National Park, various aspects need to be analyzed, including the ecological impact, social impact, economic impact, and visitor experience. The ecological impact assessment may include the assessment of the biodiversity, habitat loss, and the carrying capacity of the ecosystem. The social impact assessment may include the analysis of the impact of tourism on the

cultural heritage and social fabric of the local communities. The economic impact assessment may include the analysis of the tourism industry's contribution to the local economy and the benefit-sharing mechanism for the local communities. Finally, the visitor experience assessment may include the evaluation of the quality of services, safety, and satisfaction of the tourists.

3). Draw attention to the growing importance of sustainable development in tourism as a whole.

Sustainable development in tourism is becoming increasingly important worldwide, and Annapurna National Park is not an exception. Sustainable tourism development aims to minimize the negative impacts of tourism on the environment, economy, and society while maximizing the benefits for the local communities and visitors. The growing importance of sustainable tourism development highlights the need for creating management plans that consider the long-term environmental, economic, and social impacts of tourism. The management plan for Annapurna National Park should promote sustainable tourism practices, prioritize the conservation of the ecosystem, and create economic opportunities for the local communities while preserving their cultural heritage. The success of such a management plan will demonstrate how sustainable tourism development can contribute to the conservation of natural resources and cultural heritage while supporting local livelihoods.

2 Literature Review

Before quantitatively assessing a strategy for managing an alpine tourism destination, review current national park management schemes and consider them under the circumstances of the status quo in the Nepalese Himalayas.

2.1 Assessment of current optimal management plans in three mountainous national parks

2.1.1 Yosemite National Park: Utilizing GIS (Global Information System) to track down and regulate invasive species.

Being one of the most prominent and well-known national parks universally, Yosemite National Park attracted 3,287,595 visitors in 2021 alone [16]. Management in recreational services and environmental protection proves to be unprecedentedly important here.

Conveniently, the Yosemite Foundation Document, first published in December 2016, provides basic guidance for planning and management decisions. The core components of the foundation document include a brief description of the park as well as the park’s purpose, significance, fundamental resources and values, and interpretive themes. The foundation document also includes special mandates and administrative commitments, an assessment of planning and data needs that identifies planning issues, planning products to be developed, and the associated studies and data required for park planning. Along with the core components, the assessment provides a focus for park planning activities and establishes a baseline from which planning documents are

developed [17]. Apart from written documents, the most important feature of Yosemite's management scheme is to utilize the digital product GIS (Global Information System) to regulate and control potential risks to its ecology. The system is used to collect, store, analyze, and display geospatial data related to the park's natural resources, infrastructure, and visitors. GIS technology helps park managers to make informed decisions and plan for the future by providing accurate and up-to-date information about the park's resources and assets. Some of the approaches Yosemite National Park applies by GIS include mapping trails, monitoring wildlife populations, analyzing water quality, and managing fire risks. The system also helps park staff to coordinate emergency response efforts and communicate with visitors about park regulations and safety guidelines [18]. There are numerous ways in which invasive plant seeds can slip through the cracks of even the most rigorous prevention systems. Therefore, a system of early detection is necessary to enable a rapid management response to new invasions. The goals of the inventory component of IPM are to: Survey the park for new priority infestations, document the spread of existing infestations, document the effectiveness of the treatment, and to provide the data needed to plan invasive plant treatment operations.

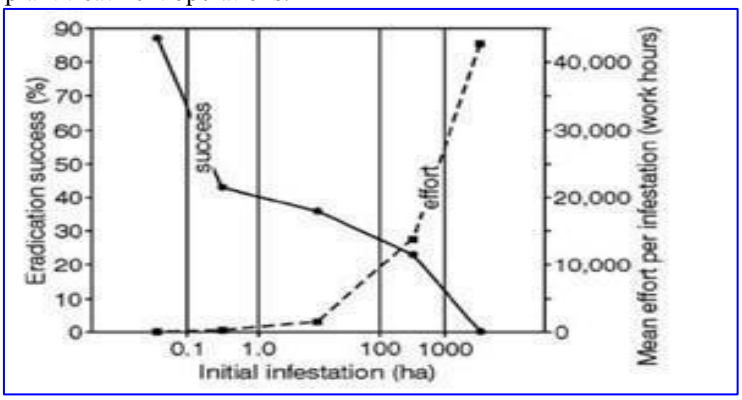


Fig. 2. As infestation size increases, the effort to control, measured in hours (and dollars) increases, while the success of eradication decreases. Credits: Management, *Yosemite National Park (*nps.gov)

Catching infestations early enables managers to respond while populations are still small and easy to manage. This is critically important because the probability of eradication is much greater when invasive plant populations are small. The management response, therefore, requires far fewer personnel, equipment, and monetary resources, and would potentially use tools that are less intrusive to the surrounding landscape. In the figure below, one can see how dramatically the cost of control increases with increasing infestation size while the chance of success declines (figure 2).

2.1.2 New Zealand National Park: Legislation and creating permanent bonds between tourism and unique cultural characteristics.

New Zealand's beautiful ecological environment is world-famous. The island is a land of breathtaking beauty, with a diverse range of landscapes that have captivated visitors for centuries. From the rugged mountains to the pristine beaches, the natural wonders of this country are truly awe-inspiring. Management for conservation facilities and zones here includes strict legislation and combining an eco-friendly tourism trend with the diversified culture that accumulates here.

The New Zealand government and park authorities attach great importance to conservation management in their well-established conservation legal system. Initially, New Zealand had many small laws on nature conservation, such as the National Parks Act. (National Parks Act 1980 No 66 (as of 28 October 2021), Public Act – New Zealand Legislation). The formal introduction of the Protection Law in 1996 consolidated the previous minor laws. From a legal point of view, the Conservation Law clarifies the two major functions of national parks: protection and recreation. The distinction in utility safeguards the rights and interests of future generations, well-raising tourists' incentives to become aware of the necessity of environmental conservation [19].

In addition, combining conservation with local cultures also plays a defining role. Maori indigenous groups are also willing to participate in the management of the park, which has become an important social force [20]. Traditional elements from "war dances" to "The Orator's Rule" are frequently present and highlight the contribution of Aboriginals who once owned this land. With respect comes cooperation. Locals are strongly supporting and even actively participating in the protection and management of high parks. Therefore, combining local cultures into managing a national park proves technically feasible and morally necessary.

2.1.3 Hong Kong Conservation Zone: Buffering against rapid urbanization.

The Hong Kong Country Park (HKCP) is located in the southern part of Hong Kong Island, with Aberdeen and Wong Hang to the south and Wan Chai Gap to the north, covering an area of about 420 hectares. Hong Kong's topography and sub-tropical climate provide a wide range of habitats to support a rich variety of flora and fauna. Scenically, it has a great deal to offer- a landscape rising from sandy beaches and rocky foreshores to a height of almost 1,000-metre high, woodlands and hilly areas covered by open grassland and a variety of scenic vistas rarely matched in such a small place. Within reachable distance for citizens from the metropolitan, Hong Kong Country Park is the ideal example of an urban nature reserve, where residents can enjoy the perfect combination of the relaxing natural environment with integrated methods of management.

Hong Kong's country parks are managed by the Agriculture, Fisheries and Conservation Department (AFCD), which is responsible for the planning, development, and management of the parks. The AFCD has developed a comprehensive management framework, which includes policies, guidelines, and regulations to ensure the sustainable use and conservation of the parks. One of the key components of the management framework is the zoning system, which divides the parks into different zones

based on their ecological value, recreational potential, and conservation needs. The zoning system helps to guide the development of different areas of the parks, ensuring that sensitive habitats are protected and that recreational activities are managed sustainably (Agriculture, Fisheries and Conservation Department (AFCD), 2019).

Another important aspect of the management framework is the enforcement of regulations and guidelines. The AFCD has established a range of regulations and guidelines to ensure that visitors to the parks behave responsibly and do not damage the environment. These include rules around littering, camping, and fires, as well as guidelines around hiking and trail use. The AFCD also employs a team of park rangers who patrol the parks and enforce these regulations. In addition to these measures, the AFCD also undertakes a range of conservation initiatives to protect the parks' biodiversity. These include habitat restoration projects, species reintroduction programs, and research into threatened species. The AFCD also collaborates with local NGOs and academic institutions to develop conservation strategies and undertake research. Finally, it is worth noting that the management of Hong Kong's country parks is subject to ongoing review and assessment. The AFCD regularly conducts surveys of park usage and visitor satisfaction, as well as ecological assessments to monitor the health of the parks' ecosystems. This information is used to inform future management decisions and ensure that the parks continue to meet the needs of both visitors and the environment (Hong Kong Government, Country Parks, 2019).

2.2 Status Quo of mountainous national parks in Nepal

Nestled in the Himalayan Mountains, Nepal has not only an extraordinary cultural heritage but also some of the most unique ecology and natural beauty in the world. Tourism is an important source of foreign exchange and, in isolated mountain regions, the only source of cash [21]. From 1970 to 1986, nearly 2 million tourists visited this country. In 1970 around 45,000 visitors came to Nepal; by 1986, the number had increased to 223,000. The number of those seeking mountaineering and trekking rose from 12,600 to 33,600 (Upadhayaya, 2018).

The current development plan for the period 1985-1990 shows a strong commitment by the Nepalese government to tourism as an avenue for future economic growth. For each of the five years, a target has been set for a 12.3 per cent increase in annual earnings through the following programs: (1) develop tourist areas in Palpa, Ilam, Mugu, Kailali, Baglung, Makwanpur, and the Annapurna Himalayan region; and (2) expand trekking routes and establish the necessary ancillary physical facilities. Although tourism is a national priority, the sheer number and demands of trekkers have increased the threats to local resources and the local people's traditional way of life.

2.3 Case Analysis in the Himalayas: Annapurna National Park

The Annapurna mountain range and its surrounding areas are part of the Annapurna National Park, with a total area of 7629 km². In the national park, there are several hiking trails (tracks), which are world-famous. More than 60% of the total number of mountain tourism lovers who come to Nepal go to the Annapurna region, which attracts

travellers with a variety of natural landscapes, as well as the opportunity to join the culture and life of the local population [22]. There are three main routes for trekking around Mount Annapurna (figure 3): Jomsom Trek, Sanctuary Trek, and Circuit Trek. Hiking around Annapurna is a rare opportunity to get to the very centre of the Himalayas and get acquainted with the original culture of the locals - Gurung, Tamang, Thakali and Pokhari. The route usually starts in ancient Kathmandu, passes through mountain paths and ends in the city of Pokhara. The geographical features of the terrain provide many micro-climates, ranging from sub-tropical conditions in the south to alpine steppe and arid conditions in the north.

The biological diversity is illustrated by a King Mahendra Trust for Nature Conservation (KMTNC) 1994 study, identifying over 1,200 plant species, 101 mammals, 474 bird species, 39 reptile species and 22 amphibian species. These include the endangered snow leopard, blue sheep, musk deer and over 100 varieties of orchid. The ACA's biological diversity is matched by its cultural diversity. The area has a population of more than 120,000 inhabitants from more than 10 ethnic groups.

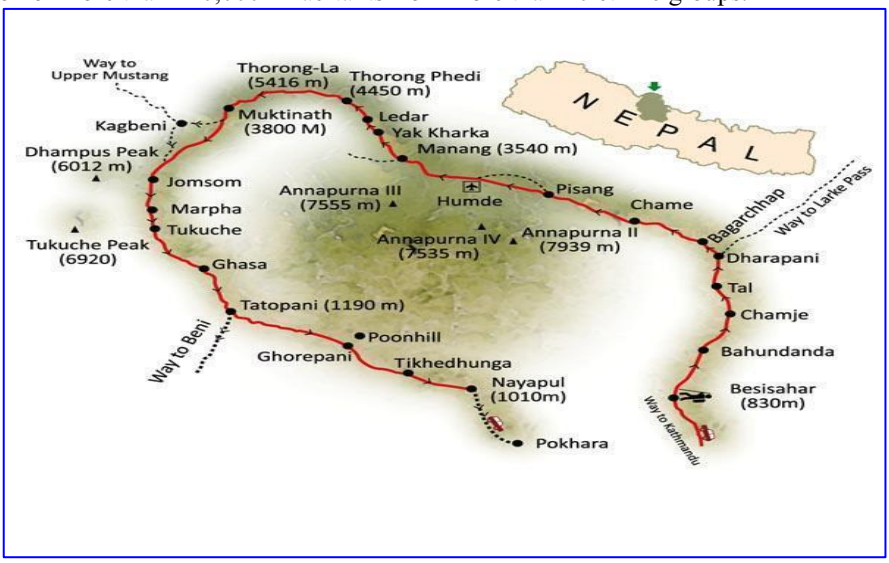


Fig. 3. Annapurna Conservation Area trekking circuit map. Credits: Hemant Albert Soreng

Aside from the stunning views of the world's highest ranges, the Annapurna area is plagued by paltry economic profits caused by low employment and limited agricultural production, as well as environmental damage caused by the steady increase of tourism-conditions that are familiar across much of the middle hills of Nepal, such as the trekking circuit in the Annapurna Conservation Area (figure 3).

2.3.1 Poor Economy.

A person working in Food / Hospitality / Tourism / Catering in Nepal typically earns around 53,800 NPR per month (around 503 USD). Salaries range from 20,400 NPR (lowest average), or 154 dollars in USD) to 150,000 NPR (highest average, actual

maximum salary is higher) at around 1134 USD. However, about 80% of employees working at Annapurna Conservation Area struggle to reach the minimum. If payment in this area cannot match average domestic income levels, tourism management jobs will unlikely succeed in the future. The geography of ACA makes it venerable to minimizing revenue. More than 95% of consumables on dinner tables in the Annapurna circuit are transported there by food trucks. With an average elevation of more than 2800 meters, it is almost impossible to grow any source of sustainable vegetation to a large extent here. Thus, the costs of food are expensive, and considering the average income is a huge scarcity. With more and more visitors each year, the ACA is unlikely to have the capability of supporting such a huge population, thus leading to man-made damage to the environment.

Fig. 4. Deforestation and treeless mountains around Kagbeni on the Annapurna Circuit. Credits: Juerg Lichtenegger

2.3.2 Huge Tolls on the Ecosystem.

The alpine ecosystem pays huge tolls for the damage done by tourism each year. Deforestation and soil erosion is a major issue (figure 4). Due to the continuing growth of tourism in ACA, locals have built lodges, hotels and restaurants, even in locations that are difficult to access. There are hot showers 4,000 m above sea level, and menus that leave nothing to be desired [23]. Many of the sparse forests were cleared to assure these comforts. The subsequent erosion has caused many devastating landslides that bring harm to residents as well as plantations and grazing facilities. A second problem is garbage. Trekkers leave up to 200,000 plastic bottles lying around the area each year. The bottles are not carried down into the cities for waste disposal [24]. On the contrary, they are dumped behind the lodges and along the track and remain there indefinitely. Soil pollution due to unorganized garbage disposal could lead to health issues such as headaches, nausea, fatigue and eye irritation, considering the poor medical services that are available in this region.

Looking closer at habitats, environmental assessments have identified biological invasions as major threats to the biodiversity in the CHAL(Chitwan-Annapurna Landscape). One of the rapidly spreading Invasive Alien Plant species (IAPs) in the CHAL is Parthenium hysterophorus L., a nontropical invasive weed of global signifi-

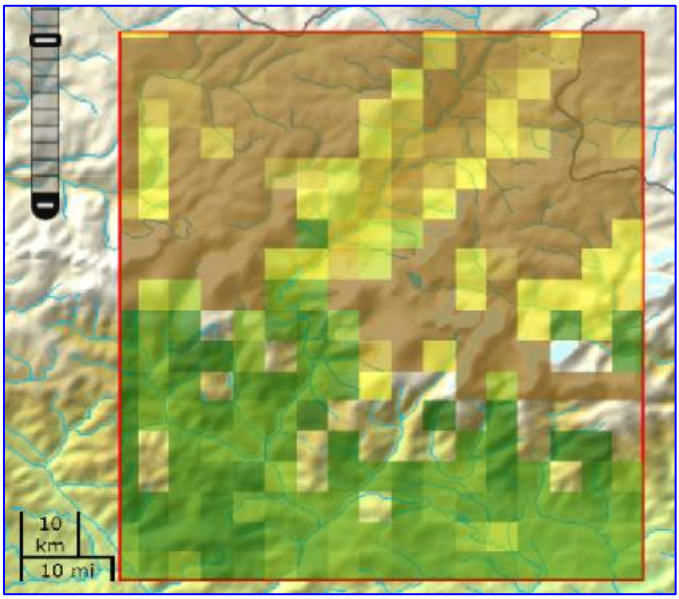
cance. The invasive species may be domesticated in the belongings of foreign tourists [25]. This in turn will result in desertification and intoxication for local species of herbs and kill off insects. Alpine ecosystems are extremely fragile in tolerance of external species due to low stability, therefore, controlling evasive plants and animals in the ACA is vital to a sustainable future.

3 Methodological Analysis

3.1 Chronological comparison of land cover at ACA using Copernicus NDVI

As part of efforts to preserve the natural resources of the area, we have turned to satellite imagery and remote sensing techniques to analyze land cover changes over time. One of the most useful tools for this type of analysis is the Normalized Difference Vegetation Index (NDVI) Copernicus. NDVI is a measure of the amount of green vegetation in an area, calculated by comparing the reflectance of near-infrared and red light. NDVI can be used to monitor changes in vegetation over time, such as changes in crop yield or forest cover. One of the key benefits of using NDVI Copernicus for land cover analysis is its ability to provide consistent data over time. Because the data set covers the entire globe, it is possible to compare changes in vegetation cover across different regions and periods. This makes it an ideal tool for monitoring land use changes, such as deforestation or urbanization. By comparing these maps with historical data, researchers can identify areas where vegetation cover has increased or decreased, and investigate the causes of these changes.

In this study, NDVI has been applied to analyze the changes in land cover over the course of 32 months, beginning from July 1st 2020 to March 10th 2023. For every 8 months, an image is collected on NDVI of the current land cover status which consists of the mean values of vegetation index after 10 days of the chosen date (eg. 8 months after July 1st 2020, an image was collected which includes mean values of land cover for March 1st to March 10th). An example is shown below with the appropriate scale of measure on the bottom left corner that shows the vegetation index in the ACA's domain (bordered by red lines) at a certain time interval. The legend at the beginning of the next page indicates what each color represents relative to land cover types in figure 5- figure 10.



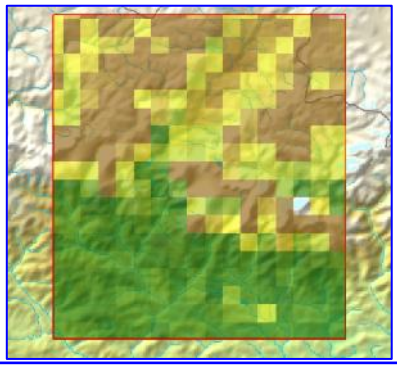
Legend

Map Domain: (28.1 N-29.18 N) (83.3 E-84.28 E)

NDVI Interpretation	Color Representation
S-Tropical Forest cover > 80%	
S-Tropical Forest cover 50%-80%	
Dense shrubs and grassland	
Grassland cover < 60%	
Grassland cover < 40%	
Alpine Grasslands and Tundra	
Tundra cover < 40%	
Barren terrain (rocks & boulders)	

Fig. 5. ACA land cover: 6.11-6.20, 2023. Copernicus NDVI

The following figures demonstrate 5 intervals between 32 months. Each figure follows the domain, scale, and coloration as the example figure and legend. Invalid data inside the domain do appear occasionally and are seen as not filled in with colors presented in the legend.



Legend

Map Domain: (28.1 N-29.18 N) (83.3 E-84.28 E)

NDVI Interpretation	Color Representation
S-Tropical Forest cover > 80%	
S-Tropical Forest cover 50%-80%	
Dense shrubs and grassland	
Grassland cover < 60%	
Grassland cover < 40%	
Alpine Grasslands and Tundra	
Tundra cover < 40%	
Barren terrain (rocks & boulders)	

Fig. 6. ACA land cover: 7.1-7.10, 2020. Copernicus NDVI

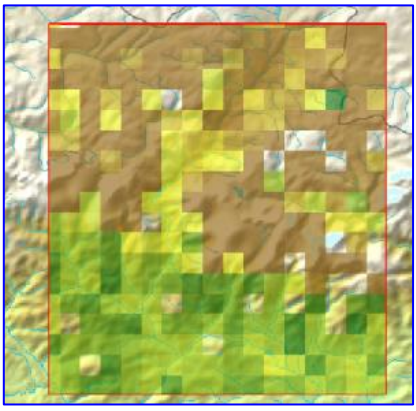


Fig. 7. ACA land cover: 3.1-3.10, 2021. Copernicus NDVI

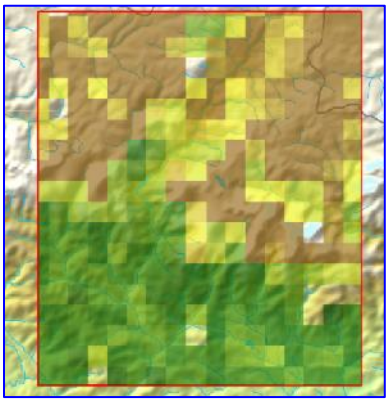


Fig. 8. ACA land cover: 11.1-11.10, 2021. Copernicus NDVI

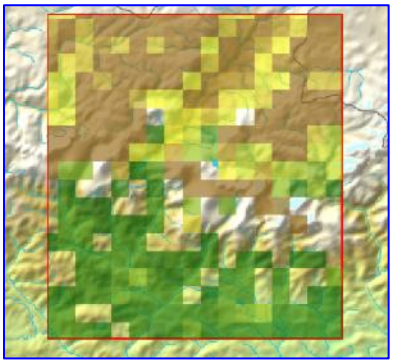


Fig. 9. ACA land cover: 7.1-7.10, 2022. Copernicus NDVI

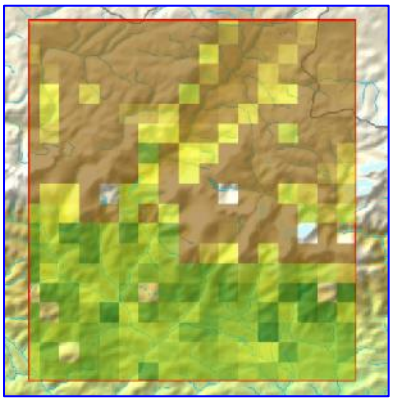


Fig. 10. ACA land cover: 3.1-3.10, 2023. Copernicus NDVI

3.1.1 Interpretations.

From what the figures present, it is not difficult to detect the trend of vegetation cover over the last three years since July 2020. Dark-green shades have become rare in southern slopes of low elevation and the North-west region has been increasingly prone to desertification as dark yellow and brown takes over. Moreover, the river channel vegetation system that flows through alpine grounds in the central-northern region has also seen a drastic decline, as it is detected by the rarity of light yellow and yellow shades.

To compare with reality, these figures demonstrate vivid reflections. Treks at ACA are long and are subjected to muti-days of travel, accompanied by several cultural and religious sites such as monasteries, temples, and shrines. Thus, visits here can take several days, and hence, the need for accommodation arises. In addition, popular accommodation areas are usually located in low-elevated, oxygen-rich regions with abundant water supply to the south of ACA. As a result, Sub-Tropical forests to the south have become less dense throughout the 32 months, mostly caused by clear-cutting to meet increased lodging demand. Apart from overnight stays, trekking also proves to have deadly impacts. The rise of tourism after the Covid-19 pandemic and the worldwide preference for outdoor travel has the ACA's trails met with devastating circumstances. The most popular trails are along stream valleys up north, where elevation is relatively low, with less harsh terrain for hiking and more convenience for water collection. Typically, constant trampling over alpine grassland which already is fragile and prone to degradation brings serious erosion issues, and it is most obviously presented in the figures as the northern river valley vegetation cover shows a dramatic decline. Both trends match respectively to the changes seen through the figures and thus strengthen the credibility of this methodology.

3.2 Soil well-being detection by layering Soil-Grid indexes to ARC-GIS topographic map

As previously mentioned, poor agriculture in the ACA can not only elevate poverty but can also cause harm to the environment. To address the current problem, identifying where grazing and crop growth can be executed cautiously seems vital. This methodology contains two special tools for assistance: Soil-Grids and ARC-GIS.

Soil-Grids is a global soil information system that provides high-resolution soil data for various soil properties such as organic carbon content, pH, and texture. It is based on a machine learning algorithm that uses various environmental factors such as climate, vegetation, and terrain to predict soil properties. Soil-Grids provides data at various resolutions ranging from 250 meters to 1 kilometer, making it an ideal tool for investigating soil properties over large areas. On the other hand, ArcGIS can be used to create maps, perform spatial analysis, and generate reports, making it an essential tool for environmental management.

In our case, Soil Nitrogen, CEC (cation exchange capacity), and Organic Carbon are the most significant components when investigating the wellness of soil and its capability for agricultural practices in Annapurna. Thus, data was downloaded respectively and layered onto a topographic terrain map of ACA with the same domain. The highest

concentrated areas of the three factors here were singled out to form a radiating Hot-Spot imagery. The figure below presents the Central Northern region of Nepal where the Annapurna Conservation Area is situated. Hot spots reflect the top 5 regions with the best soil nutrition (figure 11).

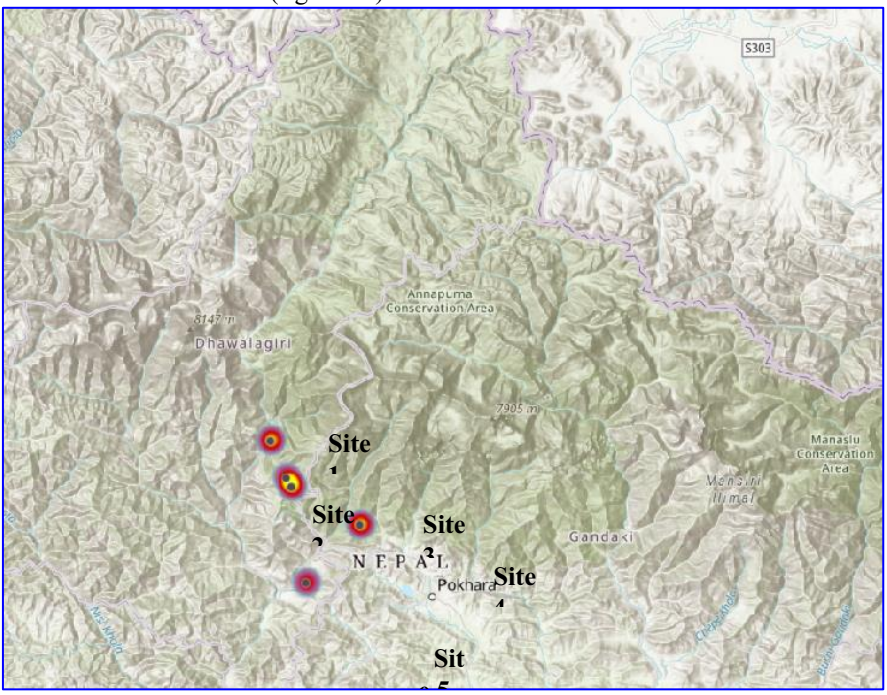


Fig. 11. Concentrated soil nutrition Hot-Spots at ACA, labeled site 1-5, May 2023. ARC-GIS

3.2.1 Interpretations.

All 5 Hot-Spots follow a distinctive pattern: situated at relatively low elevated river valleys on ridges of high-rising mountains. The reasons for this formation can be explained. Local stream systems tend to originate from melting ice water in the upper glacier zone and snow in the Himalayas. With a steep southern slope, surface soil is easily eroded with various channels, furthering the sedimentation of downstream valley grounds. As nutrients are being washed into low valley grounds where stream flow declines quickly, erosion is unlikely to happen from natural processes. Nutrients are left behind in these valleys, and with an abundant water supply and the sub-tropical climate on the southern slopes, healthy soil reveals itself.

It is also important to differentiate each Hots-Spot. Sites 1 and 4 are typical representations of alpine ridge valley sedimentation with very concentrated projection, while at Sites 2 and 3, multiple streams meet up at a low, flat plateau, depositing the most nutrients and thus projecting the highest level of soil well-being. Site 5 on the other hand is a downstream lake away from the Himalayas, where the most kinetic rivers decelerate and lay their sediments.

4 Results

4.1 Creation and Analysis of a Feasible Management Plan

Through the review of previous examples of optimal management plans in mountainous national parks and the methodological analysis of the current environmental status at the ACA region (figure 12), this section will combine efficient conservation techniques and the status locally to fabricate a sustainable management plan for Annapurna National Park.

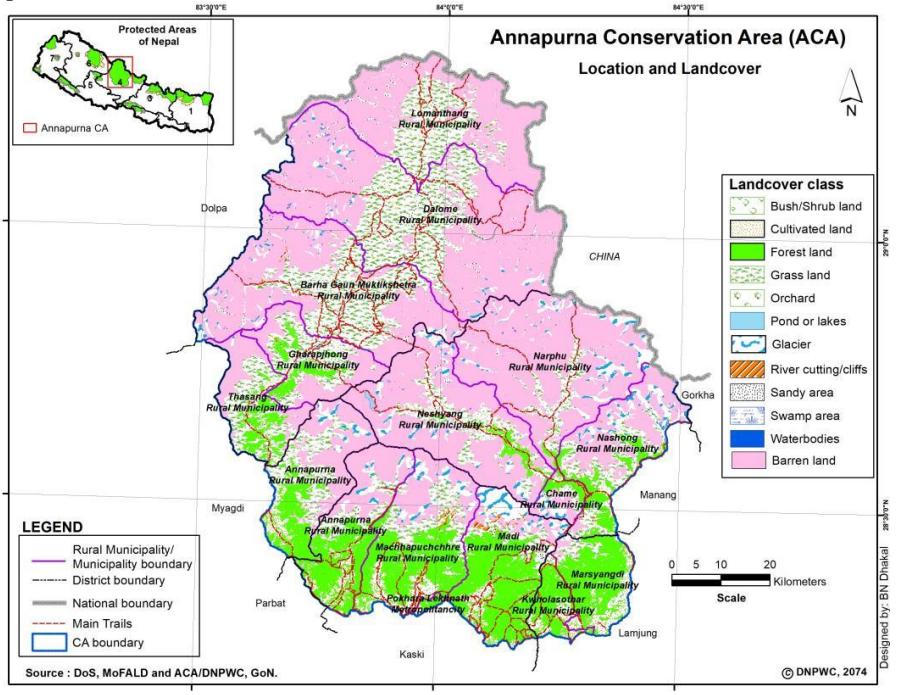


Fig. 12. ACA's geographical location and land cover. Credits: Kulendra Baral

4.1.1 Biodiversity in varying heights.

Spanning 120 km with altitudes of below 1000 m up to 8000 m, it has two distinct climatic regions. The southern belt of this range—the Pokhara region—receives the highest precipitation, while the northern belt—the trans-Himalayan region—receives the lowest precipitation in Nepal. Nepal's largest conservation area, the Annapurna Conservation Area (ACA), covers most of this range and is situated between 83°34′ to 84°25′ E and 28°15′ to 28°50′ N, covering an area of 7629 km2. ACA is rich in biodiversity, harbors 29 ecosystem types and has a wide range of habitats, from Shorea robusta to perennial snow forests, harboring 22 different forest types. Schima wallichii, Castanopsis indica, Alnus nepalensis, Pinus wallichiana and Betula utilis are the region's major tree species. Conservation techniques of species should be taken into serious consideration. However, with the tier-like spread of wildlife communities

starting with rich biodiversity in low-altitude sub-tropical climates to alpine environments up above, elevation creates unique layers of ecology.

4.1.2 Differentiating the management scheme of ACA by elevation differences.

Table 1. Dominant vegetation land cover at ACA as altitude increases. Resources gathered from Sustainability [26].

Altitude (meters)	Most dominant land cover
760m-1000m	Evergreen broadleaved trees dominated forests in low-altitude subtropical regions (Schima Wallachia, Rhododendron, and campanulate are major species found here)
1000m-2800m	Mostly Broad-leaf and coniferous species (Alnus nepalensis is the dominant vegetation here)
3000m-4000m	Alpine vegetation and pine forests (Abies spectabilis is very dominant at this altitude, tundra also covers rocky surfaces of alpine flat-lands)
4001m-5000m	Tundra and alpine grassland with a strewn community of low groves
5000m-7393m	Tundra and bald terrain

Deadly impacts of soil erosion and deforestation mentioned above have a high potential of occurring in various terrains conclusive in the table 1, if not managed with urgency. The table 2 illustrates the relationships between the altitudes and the management schemes.

Table 2. Management scheme of controlling environmental issues that occur from tourism according to vegetation index at ACA

Altitude	Management Scheme at ACA
760m-1000m	It is essential to prevent deforestation and promote afforestation here. The local communities can be encouraged to participate in tree plantation drives and create awareness about the importance of preserving the natural habitat.
1000m-2800m	Preventing forest fires and controlling illegal logging is key. The forest department can also undertake measures such as controlled burning to prevent wildfires and promote natural regeneration. Additionally, the local communities can be encouraged to practice sustainable forest management techniques like selective logging.
3000m-4000m	Prevent overgrazing by domestic livestock and promote the growth of native species. The forest department can undertake measures like fencing off certain areas to prevent overgrazing and promote natural regeneration. Additionally, the local communities can be encouraged to practice sustainable grazing techniques like rotational grazing.
4001m-5000m	Prevent soil erosion and promote the growth of native species. The forest department can undertake measures like constructing check dams to prevent soil erosion and promote natural regeneration. Additionally, the local communities can be encouraged to practice sustainable land use techniques like contour farming.
5000m-7393m	Restricting human access to certain areas which are not on track promotes natural regeneration.

Fig. 13. Annapurna trekking circuit, starting from its capital, Kathmandu, to elite climbing routes above 8000 meters. Credits: Mathilde Émond

4.1.3 Implementation of technological devices.

With such a huge land terrain, relentless work needs to be done to control invasive species manually. Referring to Yosemite's implementation of GIS in managing invasive species, GIS could also fit in this complex terrain to detect, identify and control exotic organisms, such as in the Annapurna trekking circuit (figure 13).

All public land managers, contractors, employees and volunteers should initiate data-based management of invasive species in ACA using the Field Maps app that could be installed on mobile devices. This sync to ArcGIS Online and the data is summarized in dashboards. The mapping system allows for the coordination of control work through data sharing. The Field Maps app has enhanced bio-security response by providing real-time mapping to track the spread and ensure follow-up control is not overlooked. The Mexican feather grass, fireweed and Coolatai grass incursions into the Australian Capital Territory (ACT) are good examples where the Field Maps app was the key to a successful response (figure 14).

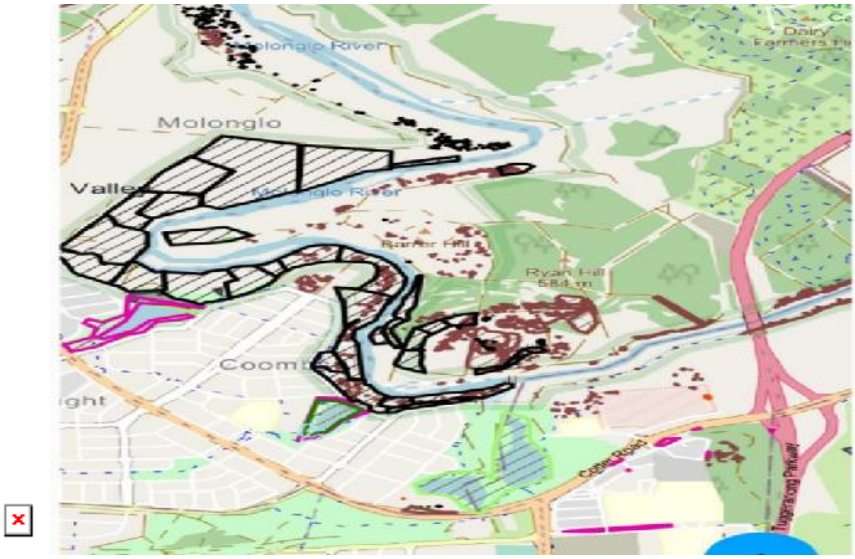


Fig. 14. Screenshot of local weed and vegetation detector on FieldMap in Canberra, ACT (Australian Capital Territory). Scattered dots of brown and black indicate invasive weeds that were detected and shaded areas indicate local habitats for marine and near-water species. Credits: Steve Taylor

4.1.4 Aligning goals with legislation and park policies.

The Notice of the State Forestry Administration on Further Strengthening the Management of Nature Reserves in the Forestry System clearly require accelerating the pace of legislation and formulating management rules or relevant laws and regulations for various nature reserves [27]; the management measures and detailed rules formulated by local government departments and protected areas according to their conditions are also an important basis for the management of nature reserves, providing a stronger guarantee for the daily management work, resource protection and sustainable utilization. To protect and manage the biodiversity, natural resources, cultural resources and special geological landform of the entire region, based on the relevant laws and regulations issued by the state, it is necessary to have special attention and management work priorities, and the formulation and promulgation of scientific policy support for the precise management and effective management of ACA.

Given the large number of protected communities and the large poverty of protected areas, the implementation of ecological compensation funds was emphasized, and a community co-management strategy combining protection and community development was proposed. Strict measures are taken to protect it, no production facilities shall be established in the core area and buffer zone, and any production facilities that pollute and damage the environment shall be eliminated in the buffer zone. Recognize units and individuals who have contributed to the management of the Everest Conservation Area.

Specifically, it is vital to clarify the responsibilities of the management agency of the ACA: protection law enforcement, resource investigation, scientific research, business guidance, community development, environmental education, external exchanges, etc. Supervise, review, guide and assist relevant departments in carrying out legal activities on ACA.

Management of Annapurna Trekking Zone includes the prohibition of production and operation in the reserve, the management system for scientific research and other activities in the zone, the planning compliance system, the strict approval and implementation management system for construction projects), the administrative approval and payment system for mountaineering and other activities, the approval and obedience management system according to law, the system for the protection and maintenance of custody facilities, and the system that new units and residents may not move into the core area and buffer zone without approval. Among them, the highlights are strict law enforcement in accordance with the Regulations of Nepal on Nature Reserves, supervision of construction projects in the reserve, and effective management of various activities carried out in ACA.

Finally, reaching out to communities to improve understanding and cooperation with natives is actively promoting the pilot work of ACA, not forgetting to strengthen the promotion and publicity of public environmental awareness on Mount Everest.

5 Conclusion

Synthesizing a sustainable management scheme for a mountainous national park or alpine conservation zone is a complex and challenging task. It requires a thorough analysis of existing and optimal strategies, as well as the proposal of innovative methods that are adaptive to the given region. In this paper, we have discussed the importance of merging innovative schemes with the status quo of the targeted alpine area to create a management plan that is effective and sustainable.

The ACA is one of the most popular tourist destinations in the world, attracting thousands of visitors every year with its extraordinary scenery and adventure experiences. However, the harshness of the local environment, deficiency in social productivity, and absence of a well-managed tourism industry have led to turbulence in economic growth, degradation of natural resources, and destruction of regional ecosystems.

The first step in our management plan is to increase social productivity through community-based tourism. This involves working closely with local communities to develop sustainable tourism practices that benefit both visitors and residents. By involving local people in tourism activities, we can create economic opportunities and promote social development while also preserving natural resources and ecosystems.

Another key aspect of our management plan is to promote responsible tourism practices among visitors. This includes educating tourists about the importance of conservation and sustainability, as well as encouraging them to engage in activities that have minimal impact on the environment. On Bioscience Biotechnology Research Communication journal, the public education will bring positive effects. In addition to

key reforms in mandatory schooling n terms of increased quality of investment, utilization of information, communications hold considerable promise improving educational outcomes" (Shaturaev, 2021). Promoting responsible tourism practices, we can reduce the negative impact of tourism on the environment and ensure that the ACA remains a pristine and beautiful destination for future generations.

In addition to these measures, our management plan also includes initiatives to promote renewable energy, reduce waste, and protect biodiversity. By implementing these measures, we can create a more sustainable future for the ACA while also promoting economic growth and development.

In a nutshell, synthesizing a sustainable management scheme for a mountainous national park or alpine conservation zone requires a comprehensive analysis of existing and optimal strategies. By combining innovative schemes with the status quo of the targeted alpine area, we can create a management plan that is effective and sustainable. Our tentative management plan for the Annapurna Conservation Area is designed to enhance revenue while decreasing the rate of resource exploitation. We believe that this plan will help to create a more sustainable future for the ACA, its people, and its unique ecosystem.

References

1. Tourism and its impact on livelihood in Manaslu conservation area, Nepal,A KC, RB Thapa Parajuli,Environment, development and sustainability, 2014.
2. Climate change and its impact on tourism in Nepal,KC Anup, Journal of Tourism and Hospitality Education, 2017.
3. Implications of climate and environmental change for nature-based tourism in the Canadian Rocky Mountains: A case study of Waterton Lakes National Park,D Scott, B Jones, J Konopek, Tourism management, 2007.
4. Paradox of mountain tourism: Case references from the Himalaya, TV Singh, J Kaur, Tourism Recreation Research, 1986.
5. Nepalese Ministry of Culture, Tourism and Civil Aviation, 2022.
6. Environmental impact assessment of mountain tourism in developing regions: A study in Ladakh, Indian Himalaya,D Geneletti, D Dawa, Environmental impact assessment review, 2009.
7. Assessing the environmental impact of mountain tourism. The case of Elatochori Ski centre, Greece, S Tsiaras - Red (Intermediate), 2015.
8. Land management explains major trends in forest structure and composition over the last millennium in California's Klamath Mountains, CA Knight, L Anderson, MJ Bunting, National Acad Sciences,2022.
9. Recreation impacts and management in wilderness: A state-of-knowledge review, YF Leung, JL Marion, Wilderness science in a time of change, 2000.
10. Tourism in the most fragile environments, R Buckley, Tourism Recreation Research, 2000.
11. Nature and people in the Andes, East African Mountains, European Alps, and Hindu Kush Himalaya: current research and future directions, D Payne, M Snethlage, J Geschke, EM Spehn, Mountain Research, 2020.
12. The concept of sustainable development: definition and defining principles, R Emas - Brief for GSDR, 2015;Sustainable development: a new world deception, B Willers, Conservation Biology, 1994.

13. Responsible tourism towards sustainable development: Literature review and research agenda, S Mondal, K Samaddar, Trends in Asia Pacific Business, 2022.
14. A perspective on environmental sustainability,P Sutton, Commissioner for Environmental Sustainability, 2004.
15. Frontier tourism development and inequality in the Nepal Himalaya, RB Bennike, MR Nielsen, Journal of Sustainable Tourism, 2023.
16. Nepal Tourism Board, 2023 https://ntb.gov.np/.
17. US National Park Serveice, 2016 https://doc.govt.nz.
18. Management, Yosemite National Park (U.S. National Park Service) (nps.gov), 2022.
19. General Policy for National Parks, National park management (doc.govt.nz).
20. Indigenous people and nature: a tradition of conservation (unep.org).
21. Climate change and its impact on tourism in Nepal, KC Anup, Journal of Tourism and Hospitality Education, 2017.
22. Tourism development and environmental management in Nepal: A study of Sagarmatha National Park and the Annapurna Conservation Area Project, with G Walder, Bournemouth University, Bournemouth, UK, 2000.
23. Annapurna Conservation Area Project (ACAP), National Trust for Nature Conservation, https://www.ntnc.org.np
24. Nepal Tourism Board, 2021 https://ntb.gov.np/.
25. Predicting suitable habitat of an invasive weed Parthenium hysterophorus under future climate scenarios in Chitwan Annapurna Landscape, Nepal, S Maharjan, BB Shrestha, MD Joshi, A Devkota, Journal of Mountain, 2019.
26. Efficacy of Spatial Land Change Modeler as a forecasting indicator for anthropogenic change dynamics over five decades: A case study of Shoolpaneshwar Wildlife, R Gupta, LK Sharma, Ecological Indicators, 2020.
27. Aligning goals with legislation and park policies. Lin Hufa [2011] No. 187), (1996-2010).