EVALUATING THE POTENTIAL OF BLUE CARBON ECOSYSTEM RESTORATION FOR CLIMATE CHANGE MITIGATION IN PAKISTAN

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Abstract

Climate change has badly affected the earth's population and ecosystems as it raises sea levels, increases ocean temperature, and increases extreme weather events. In order to mitigate the impact of harsh weather Nature-based solutions including blue carbon ecosystem, biological fertilizer implementation, and restoration of forests gained the attention of the world. The current study evaluates the expected outcomes of blue carbon ecosystem restoration to reduce the impact of global warming in Pakistan. Pakistan has better coastal regions with adaptive blue carbon tools, but the man-made practices and deforestation of these areas reduce the blue carbon availability. This article emphasized available blue carbon resources, sequestration rates, and restoration opportunities.

It was observed that changes in the strategies for the restoration of the blue carbon ecosystem in Pakistan could be a major carbon sequestering tool, and it will also provide co-benefits including coastal protection, biodiversity conservation, and sustainable livelihoods. This research provides crucial evidence to support Pakistan's climate action planning and to integrate blue carbon into the country's broader sustainability and resilience agenda.

Key Words: Nature-Based Solution, Sequestration, Restoration, Blue Carbon, Revitalizing

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1. Introduction

It is a great lament that Pakistan, akin to numerous other nations worldwide, has witnessed a discernible uptick in global atmospheric and hydrospheric temperatures[2]. This thermal intensification has resulted in several observable changes to the ecosystem, including a rise in global mean sea levels. Widespread reduction in the coverage and volume of ice and snow across the planet, and alterations to air and ocean circulation patterns. Modifications to local and regional weather phenomena particularly changes to seasonal precipitation regimes[3] . The climatic shifts experienced in recent times represent significant perturbations to the Earth's interconnected geophysical and biophysical processes, with far-reaching implications for natural and human systems globally [4]. Such alterations occur primarily due to the heat accumulation in the climate system resulting from the increasing amount of greenhouse gases (GHGs) in the air. Furthermore, the intensification of human activities like burning fossil fuels, removal of forests, mechanization of agriculture, and land-use modifications are increasing the quantity of 'heat-trapping' GHGs in the air[5]. Since 2014 Pakistan experienced drastic climate changes which make it difficult for the local population to survive. Pakistan has experienced an increase in average temperatures, while few regions are experiencing record-breaking heatwaves. This will ultimately increase the frequency and intensity of flooding, droughts, and other related events. These will ultimately impact natural ecosystems and human communities. It will not only affect temperature and rain, but it also suppresses the growth of marine and land species by habitat loss and potential extinction.

The "Blue Carbon" terminology was initiated in 2009 in order to emphasize the environmental saving role of marine and coastal ecosystems. These ecosystems are comprised of mangroves, seagrasses, and salt marshes. They are small plants easily grown in sea setups and can capture and store significant amounts of carbon.

As per the claim of the United Nations Climate Action Report, these ecosystems can capture four times more carbon as compared to terrestrial forests. It helps them to use it as a better carbon sequester agent. Mangroves are reported to store 18 times more carbon-capturing ability as compared to other forests.[6] The recent deterioration and bad

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[2]Khan, Asad Ali, Muhammad Meraj, and Hafiza Marium Asif. (2024)"A multi-dimensional exploration of university students' sustainable consumption and environmental awareness in Pakistan." *Journal of Management Info* 11, no. 1: 102-122.

[3] Adnan, M., Xiao, B., Bibi, S., Xiao, P., Zhao, P., & Wang, H. (2024). Addressing current climate issues in Pakistan: An opportunity for a sustainable future. *Environmental Challenges*, *15*, 100887. https://doi.org/10.1016/J.ENVC.2024.100887

[4] Steffen, Will, Katherine Richardson, Johan Rockström, Hans Joachim Schellnhuber, Opha Pauline Dube, Sébastien Dutreuil, Timothy M. Lenton, and Jane Lubchenco. (2020) "The emergence and evolution of Earth System Science." *Nature Reviews Earth & Environment* 1, no. 1: 54-63.

[5] Arif, Nadjiyeva Almaz. (2024) "Characteristics of the Distribution of Greenhouse Gases into the Atmosphere." in *the 1st international scientific and practical conference "advanced technologies for the implementation of new ideas"(january 09-12, 2024) brussels, belgium. International science group. 2024. 349 p.*, p. 24.

[6] Sanderman, Jonathan, Tomislav Hengl, Greg Fiske, Kylen Solvik, Maria Fernanda Adame, Lisa Benson, Jacob J. Bukoski et al. (2018)"A global map of mangrove forest soil carbon at 30 m spatial resolution." *Environmental Research Letters* 13, no. 5: 055002.

land management practices of human beings disturbed this important natural carbon sequester tool and disturbed the ecosystem by not only releasing the stored carbon but also closing the door of future blue carbon adjustments.

These services include coastal protection, water purification, and nursery grounds. This supports commercial activities and livelihood expenses of coastal communities by promoting the growth of marine species.[7] [8] . In recognition of the importance of conserving and restoring blue carbon ecosystems, the international community has advocated for concerted efforts to incorporate their protection and management into climate change mitigation strategies by safeguarding and enhancing these natural carbon sinks, we can harness their remarkable potential to contribute to the global fight against the climate crisis while simultaneously preserving the rich biodiversity and invaluable services they offer to both marine and human systems.[9]

2. Coastal Ecosystems in Pakistan

The coastline of Pakistan is approximately 1,001 kilometers and an extensive EEZ covering 290,000 spanning the provinces of Sindh and Balochistan, lying between 24° and 25° N latitude and 61° and 68° E longitude. The diverse climate and physical traits of the coastal regions of Pakistan are ideal for supporting vast biodiversity, such as mangroves, coral, and reefs. Ramsar convention wetlands, national parks, beaches where sea turtles' nest and animal sanctuaries are some of the hotspots for biodiversity. There are 19 total Ramsar sites including eight Ramsar sites in different locations of Sindh and Balochistan[10] [11].

3. International Trends Related to Blue Carbon

The 21st Conference of the Parties (COP21) was held on December 12, 2015, where the issue of increasing greenhouse gas (GHG) emissions was discussed under the United Nations Framework Convention on Climate Change (UNFCCC). This agreement

[7] Mcleod, Elizabeth, Gail L. Chmura, Steven Bouillon, Rodney Salm, Mats Björk, Carlos M. Duarte, Catherine E. Lovelock, William H. Schlesinger, and Brian R. Silliman. (2011) "A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2." *Frontiers in Ecology and the Environment* 9, no. 10: 552-560.

[8] Duarte, Carlos M., Jiaping Wu, Xi Xiao, Annette Bruhn, and Dorte Krause-Jensen. (2017)"Can seaweed farming play a role in climate change mitigation and adaptation?." *Frontiers in Marine Science* 4: 100.

[9] Stevens, Ian T., Tristram DL Irvine-Fynn, Arwyn Edwards, Andrew C. Mitchell, Joseph M. Cook, Philip R. Porter, Tom O. Holt et al. (2022) "Spatially consistent microbial biomass and future cellular carbon release from melting Northern Hemisphere glacier surfaces." *Communications Earth & Environment* 3, no. 1: 275.

[10] Siddiqui, Pirzada JA, Sumera Farooq, Seema Shafique, and Zafar Farooqi. (2008) "Conservation and management of biodiversity in Pakistan through the establishment of marine protected areas." Ocean & Coastal Management 51, no. 5: 377-382.

[11] Mahar, Gohar Ali, Razzaq Ahmed, Muhammad Jawed Iqbal, and Muhammad Azam. (2019)."Tsunami threat versus development activities along the coast of Pakistan: a geographic assessment." Glob Nest J 21, no. 3 (2019): 347-354.

was known as the Paris Agreement which was signed by 106 countries. The agenda was discussed and emphasized on limit the rise in average global temperature to well below 2°C, and to pursue efforts to limit it to 1.5°C above pre-industrial levels[12].

The Paris Agreement's "Enhanced Transparency Framework" ETF requires signatories to monitor their progress towards meeting the agreement's goals and nations like Pakistan will have the opportunity to assess their existing situation and plan and implement the required steps to create a roadmap that would allow them to report for ETF by 2024. In addition, the Agreement mandates that nations create, update, and disseminate their Nationally Determined Contributions (NDCs), as well as create short- and long-term action plans for mitigating the effects of climate change and transitioning to low-carbon, resilient economies. Financial flows must also be aligned with the climate actions committed to under the NDCs. Every five years, nations are required to amend their NDCs with more ambitious pledges.[13]

Coastal zone management is the most mentioned adaptation mechanism in the NDCs of the majority of nations, with conservation, preservation, and restoration initiatives coming in second. Blue carbon was included in the first NDCs. A few nations are prioritizing identifying fragile ecosystems and designating them as protected areas so that they may be effectively managed. It is believed that Nature-based solutions (NbS) are fundamental, essential, and affordable technology-based solutions and these can help to achieve NDCs. It was reported that 10 - 12 giga tons of CO2 mitigation, and management are required till 2030 in order to stabilize and restore the environment[14]. Mangrove restoration and conservation are essential elements of Sustainable Development Goal (SDG) 14, "Life below Water," which aims to harness oceans, seas, and marine resources sustainably.[15]

4. **Methodology**

A comprehensive and multifaceted approach has been involved in assessing the impact of blue carbon restoration efforts in Pakistan. The initial step involves establishing a robust baseline to understand the status of the country's blue carbon ecosystems, such as

[12] Rosenstock, Todd S., Andreas Wilkes, Courtney Jallo, Nictor Namoi, Medha Bulusu, Marta Suber, Damaris Mobi, et al. (2019) "Making trees count: Measurement and reporting of agroforestry in UNFCCC national communications of non-Annex I countries." Agriculture, Ecosystems & Environment 284: 106569.

[13] Nadeau, Kari C., Ioana Agache, Marek Jutel, Isabella Annesi Maesano, Mübeccel Akdis, Vanitha Sampath, Gennaro d'Amato, Lorenzo Cecchi, Claudia Traidl-Hoffmann, and Cezmi A. Akdis. (2022) "Climate change: a call to action for the United Nations." *Allergy* 77, no. 4: 1087-1090.

[14] Podrecca, Matteo, Marco Sartor, and Guido Nassimbeni. (2022) "United Nations Global Compact: where are we going?." *Social Responsibility Journal* 18, no. 5: 984-1003.

[15] UNDP, SCBD. "UNEP-WCMC (2021)." *Creating a Nature-Positive Future: The contribution of protected areas and other effective area-based conservation measures*.

mangrove forests, seagrass beds, and salt marshes. The methodology dependent on data obtained through field surveys and remote sensing was used for data analysis. This methodology was adopted in order to determine the level of carbon sequestration in the ecosystem where mangroves are present in good quantity.

During the visit to these areas, interactions were held with local communities to inquire about the effects of pollution on their livelihoods and community resilience. The experience and insight of local communities are very important factors in such studies as stakeholder identifies the most important issues faced by them and it helps in better facilitation. In the current study, the researchers has identified the better approaches for sustainable restoration of mangroves and ecosystems in these areas. This assessment helps to identify the policies and opportunities for the better integration of the blue economy within the existing local setup. This will help to adopt a better approach for the restoration of the environment, increase blue carbon, and provide better solutions against environmental, economic, and social challenges faced by local communities. Currently, mangrove forests are found along Pakistan's coastline in five different locations: Sandspit, Sonmiani, Kalmat Khor, Jiwani, and the Indus Delta, which has the most mangrove coverage Most of Pakistan's mangrove forests are in the Indus River Delta, particularly in the Sindh province. These mangroves are considered the largest dry-climate mangroves globally, covering an area of around 600,000 hectares. In Balochistan, the mangrove forests are found along the coastlines of Milani Hor, Kalmat Hor, and Gwadar Bay, although they are more limited in extent compared to Sindh.[16] [17]

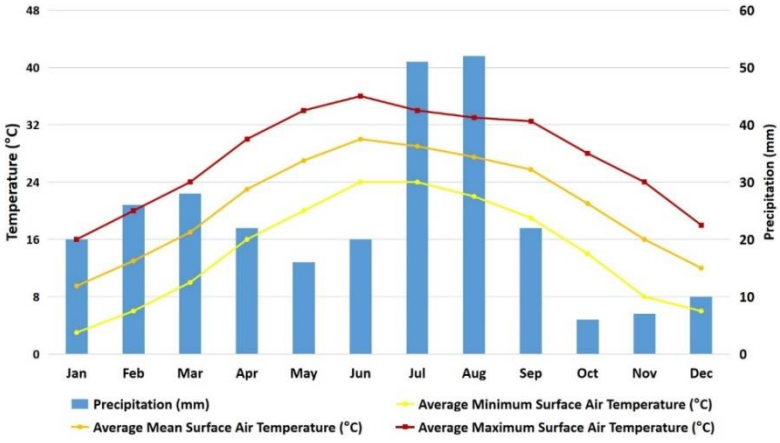

Figure 1: Average monthly maximum, minimum, and mean temperature, and precipitation conditions of Pakistan (1991-2022) Source: World Bank Group climate change knowledge portal.

Figure 1 depicts the precipitation levels and surface air temperature patterns over a period. The blue bars represent the precipitation levels, showcasing the variation in rainfall throughout the time frame. The yellow dotted line corresponds to the average minimum surface air temperatures, providing insights into the lowest temperature recordings during the observed period. The orange line represents the average mean surface air temperature, indicating the overall thermal conditions experienced on average. The red dotted line depicts the average

[16] Gilani, Hammad, Hafiza Iqra Naz, Masood Arshad, Kanwal Nazim, Usman Akram, Aneeqa Abrar, and Muhammad Asif. (2021) "Evaluating mangrove conservation and sustainability through spatiotemporal (1990–2020) mangrove cover change analysis in Pakistan." *Estuarine, Coastal and Shelf Science* 249: 107128.

[17] Khan, Muhammad Rafique, Sajid Rashid Ahmad, and Shakeel Ahmad. (2023) "Climate Change Impact on Mangrove Forests in Pakistan." In *Disaster Risk Reduction in Agriculture*, pp. 277-291. Singapore: Springer Nature Singapore

maximum surface air temperatures, highlighting the highest temperature readings recorded within the time frame. The data reveals that the surface air temperatures rise significantly during the summers, clearly defining the level of warmth and high-heat conditions experienced in the weather. However, as time progresses, the temperatures face a noticeable decline, suggesting that the intensity of heat does not remain constant, but rather diminishes compared to the summer peak. This seasonal temperature variation is a common meteorological pattern, with summers typically exhibiting higher temperatures and the subsequent months experiencing a gradual cooling trend. Understanding these temperature fluctuations is crucial for weather forecasting, planning, and adapting to the changing climatic conditions in the region.

Table 1: distribution and status in the percentage of overall mangrove forests in Pakistan in 2022, based on the specified areas: Areas denoted by numbers: 1: Jiwani, 2: Kalmat Khor, 3: Sonmiani 4: Sandspit 5: Indus Delta

Area	Mangrove Forest Distribution (%)	Status
Jiwani	2%	Limited, sparse cover
Kalmat Khor	3%	Decreasing, localized
Sonmiani	5%	Moderate but stable
Sandspit	10%	Healthy and growing
Indus Delta	80%	Largest, significant loss

Table 1 depicts the distribution of mangrove forests along the coastline of Pakistan. The data presented in the table provides a spatial representation of the mangrove ecosystem in the region. The table shows that the Indus Delta region exhibits the highest concentration and abundance of mangrove forests compared to other coastal areas along the Pakistani coastline. Regions such as Jiwani, Kalmat Khor, Sonmiani, and Sandspit also have a notable presence of mangrove vegetation. Still, the Indus Delta stands out as the primary hotspot for this important coastal ecosystem. Mangrove management in Pakistan falls under two main jurisdictions: (i) the Sindh Forest Department and Port Qasim Authority**, managing areas declared as Protected Forests, and (ii) the Board of Revenue, overseeing state-owned (wasteland) lands with mangrove presence but lacking formal forest status. The former focuses on conservation, while the latter requires interdepartmental coordination for protection. There are four different types of mangroves present in the Indus Delta are Avicennia marina (Grey Mangrove), Rhizophora mucronata (red mangrove), Ceriops tagal (Indian mangrove) and Aegiceras corniculatum (black mangrove).[18] These diverse mangrove ecosystems are estimated to sequester around 0.35 million tons of carbon dioxide equivalent per year, with a total carbon storage capacity of approximately 7.2 million tons. However, Pakistan's mangrove forests have

[18] Afsar, Nuzhat, Farah Naz, Noor Us Saher, Shafaq Ibrahim, Hafiza Mahzaib Sadiq, Urooba Ahmed, Ramsha Mughal, Syeda Zainab, and Sonia Abdul Jabbar. (2022) "Molluscans Species Diversity and Protein Expression Analysis in Lunella Coronata Spp ofFamily Turbinidae from the Manora Channel Karachi, ".Pakistan*Pakistan Journal of Marine Sciences* 31, no. 1: 75-84.

faced threats in recent years due to factors such as deforestation, land use changes, and unsustainable agricultural practices. To address this, various projects are now focused on the restoration of mangroves along the country's coastlines. The coastal regions of Pakistan, spanning the provinces of Sindh and Balochistan, exhibit distinct climatic and physical characteristics. The coastline in Sindh has great influential monsoon weather because of the strong weather attraction through Indus Delta. It is one of the world's great and strong delta as it contains creeks, mudflats, wetlands, and continental shelf. This helps it to keep and preserve mangrove forests.[19]

Instead, the coastline in Balochistan does not experience a lot of monsoons because of its climate nature i.e., the Mediterranean. It contains long beaches, sand hills, and rocky shores. It directly influenced on Mangrove population and decreased its growth. But as the rocky and dry weather in Balochistan maintains its human population to a certain number, the mangrove available in the region is not sufficient for the local environment and marine life. Pakistan contains different ecosystems, and different types of mangrove forests which are essential for carbon sequestration. It also helps to support the life of coastal communities, prevent erosion, and maintain the ecosystem in the ocean. Any effort to preserve and restore this asset is the major requirement of time as the recent increase in temperature will be very dangerous for living beings in this region of the earth.

5. A5 REDD+ Project

REDD+ is the abbreviation of "Reducing Emissions from Deforestation and Forest Degradation in developing countries. It plays an essential role in the conservation, sustainable management and enhancement of forest carbon stocks. Pakistan needs to fulfill the requirement as per the Cancun Agreement of UNFCCC. Moreover, the World Bank and the Government of Pakistan signed an agreement in June 2015, in order to prepare the country for REDD+. The project costs $3.8 million. The main focus of REDD+ actions includes consistent with the objectives of national and international forest programs, transparent and effective national forest governance structures, conserve the rights of indigenous peoples and local communities as per United Nations Declaration on the Rights of Indigenous Peoples, involve relevant stakeholders, conserve natural forests and biological diversity, address the risks of reversals, and also reduces the displacement of emissions.[20]

6. Blue Carbon Initiatives in Pakistan

Climate change is the defining challenge of our century, and Pakistan finds itself on the frontlines. As the 6th most populous nation, with over 30% living in poverty, Pakistan's

[19] Inam, Asif, Peter D. Clift, Liviu Giosan, Anwar Alizai, Samina Kidwai, Muhammad I. Shahzad, Ibrahim Zia et al. (2022) "The geographic, geological, and oceanographic setting of the Indus River–an update." Large Rivers: Geomorphology and Management, Second Edition: 488-520.

[20] Morita, Kanako, and Ken'ichi Matsumoto. (2023)"Challenges and lessons learned for REDD+ finance and its governance." Carbon Balance and Management 18, no. 1: 8.

arid and semi-arid geography makes it the 5th most vulnerable country to climate change impacts. The Indus Delta, a 230-kilometer coastal region in Sindh province, is considered ground zero for environmental and climate-related impacts. These vital tidal wetlands and mangrove forests are crucial natural defense against rising seas and coastal erosion. But they faced grave threats from human disturbances.

In 2015, Indus Delta Capital and the Sindh government launched the Delta Blue Carbon Project - a pioneering initiative to secure and restore these precious ecosystems. The goal is to shield the mangrove forests from human impacts rehabilitate and restore degraded lands through sustainable management with local communities' implement and enact policies to support sustainable development and minimize deforestation to raise awareness and build capacity among stakeholders. Through this ambitious 60-year program, the project aims to protect the existing 102,000 hectares of mangroves and restore another 226,000 hectares of degraded lands. The impact of climate mitigation and adaptation is truly transformational.

It became a globally recognized program, and the Delta Blue Carbon Project was highlighted as a success story at COP25 (Conference of Parties) in Madrid. It demonstrates how comprehensive, community-driven conservation can tackle Pakistan's pressing climate challenges head-on. The future of the Indus Delta, and Pakistan's climate resilience, rests on the success of this groundbreaking initiative.

According to [21] the mangrove forests in the Indus Delta sequester around 0.35 million tons of carbon dioxide equivalent per year. The total carbon storage capacity of Pakistan's mangrove ecosystems is estimated to be around 7.2 million tons. Studies also published that to date, more than 90,000 hectares (of a planned 220,000) have already been planted. The project expects to remove 142 million tons of CO2 from the atmosphere. From these efforts, it will generate more than 128.5 million high-quality, nature-based removal credits over its 60-year lifespan. These delta blue carbon projects aim to restore and conserve the mangrove forests while creating sustainable livelihood opportunities for local communities and enhancing their resilience to the impacts of climate change.

7. **Discussion**

Blue carbon became part of the first national Change decision taken in many countries of the world within the scope of the Paris Agreement. Blue carbon Ecosystems including mangroves, tidal marshes, and seagrasses have high NbS values. Pakistan has two coastal regions: Sindh and Balochistan, both of which have coastal Ecosystems. The Sindh's Indus Delta ecosystem is considered the seventh largest of such Ecosystems throughout the world. But over the years, Pakistan's coastal ecosystems have been largely

[21] Ahmed, Waqar, Ying Wu, Samina Kidwai, Xiuzhen Li, Tariq Mahmood, and Jing Zhang. (2021)"Do Indus Delta mangroves and Indus River contribute to organic carbon in deltaic creeks and coastal waters (Northwest Indian Ocean, Pakistan)?." Continental Shelf Research 231: 104601.

exploited for short-term profits. Pakistan has formulated the National Climate Change Policy (NCCP) 2012 and Climate Change Management Policy (2014-2030). Sindh has passed the Sindh Environmental Protection Act (SEPA), 2014, which Creates legislation related to climate change and the environment. The mangrove Area is approximately 1,464 square kilometers. According to the latest research data from 2020, mangroves and tidal marshes collectively store approximately 21 million tons of organic carbon, equivalent to 76.4 million tons of carbon dioxide (CO_2). Along Pakistan's coastline mangroves stretching approximately 1050 kilometers, with around 350 kilometers in Sindh and 700 kilometers in Balochistan—there are eight identified coastal sites. Currently, mangroves are found in five major locations along Pakistan's coast: the Indus Delta (which holds the largest mangrove cover in the country, accounting for 80% of the national mangrove area), Sandspit, Sonmiani, Kalmat Khor, and Jiwani (entirely).

8. Conclusion

The purpose of the article was to gather information about local communities' involvement, knowledge contribution, and potential financial gains in blue carbon restoration efforts. Reactions demonstrate the diverse involvement of communities, emphasizing their essential function in guaranteeing the prosperity and durability of these programs. The A5 REDD+ project aims to increase blue carbon research and awareness in Pakistan through education, training, and collaboration. This can contribute to achieving SDG 4 (Ensuring quality and equity in education), SDG 5 (Ensuring access to gender equality), and SDG Development Goal 8 (supporting sustainable economic growth) (15). Blue carbon ecosystems provide better ecosystem services in terms of protection of coastal areas, support in fish harvesting, promote biodiversity, filter water, and climate protection. It also promotes the tourism industry. Quantifying and assessing these ecosystems can help support collective payments in the future. Analyzing these services can guide future management and restoration strategies. Collaborating with local and international experts using modeling techniques and estimating coastal waters contributes to the development of accurate, science-based strategies for sustainable marine resource management, enabling informed decision-making and policy formulation to protect and optimize the use of coastal ecosystems.

Pakistan currently spends approximately 6% of its annual government budget on combating the effects of climate change. 14.327 billion Pakistani rupees are allocated in 2021-2022, and 9.5 billion Pakistani rupees will be allocated in 2022-2023. Pakistan's Ecosystem Restoration Initiative (ESRI) completed the Ecosystem Restoration Facility (ESRF) in December 2019.