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Fluctuating Climates of Himachal Himalayas: Impacts, Adaptations and Sustainable Strategies

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Abstract: ***The Himalayas are being called as "Third Pole"of Earth as they contain rugged and massive high altitude peaks covered by huge glaciers and comprises of numerous streams. Himachal Himalayas are the youngest of them and makes central part of Indian Himalayan system. Nine river systems drain through Himachal Himalayas and make possible of livelihood of about 6.86 million inhabitants around these river basins. Atmospheric circulation, agriculture and biodiversity of these regions rely directly or indirectly upon these water resources. Global warming has drastically impacted glacial covers and downstream water availabilities and facing threats due to warming temperatures. Due to complex and extreme topography, Himachal Himalayas are lacking thorough study and research as compared globally and need urgent attention and strategic implications.***
Keywords: Himalayas, Himachal Himalayas, Glaciers, Global warming, Climate change, Agro- ecological zones, Impacts and Strategies.

I. INTRODUCTION

Cryosphere of the Earth is experiencing alarming impact of climate change induced by human. Rapid reduction of ice mass over glaciers is the most widely reported impact of climate change. Global warming is melting ice over Arctic and Antarctic regions. Similarly Himalayas being called as "Third Pole" of earth are on unprecedented climatic changes due to rising temperatures. Other social and environment related issues are superseded by these alerting climatic change impacts [6].

Himachal Himalayas being the youngest among the Indian mountain system stretches for about 2500 km from North West to South East and forms about 300 km wide arcuate mountain belt. This "Adobe of Snow" is central part of Indian Himalayan Region. About 17% of Indian Himalayan Region remain permanently under snow cover while about 40% makes seasonal snow covers and thus produce water reservoirs for irrigation, drinking and hydro- power generation.

Himachal Himalayas are source of nine river systems (Fig. 1). These river basins comprises of about 4160 square km area and about 2554 main glaciers. About 6.86 million people are inhabitant of these nine river basins and total GDP as well as other basic environmental services, directly or indirectly, rely on natural resources of these river basins [13], [10], [20], [11], [16], [8], [15]. According to "The Economics of Climate Change" a drastic U- turn can be faced by human development by this mid century unless some important measures are taken now [18].

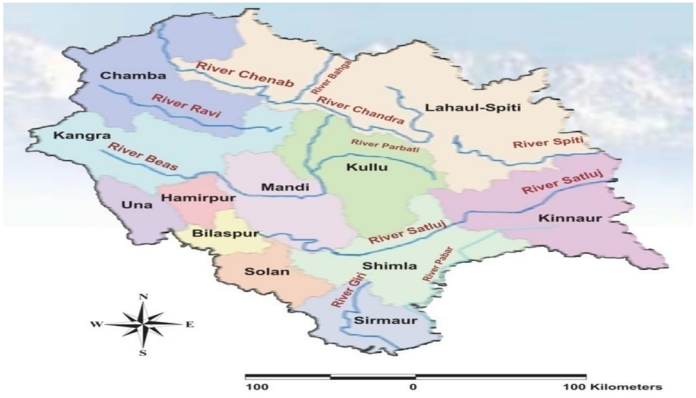


Fig. 1 Major river systems of Himachal Himalayas

The only objective of this paper is to draw attention about climatic changes taking place in mountain ranges of Himachal Himalayas. This region is comprises of highly fragile geology and environment and is vulnerable towards higher temperatures. Also, this region is not getting the required attention of environmentalists about what really is happening within this highly sensitive environmental zone. A worldwide effort is needed to preserve and save this mighty asset from impacts of global warming and climate changes.

II. CLIMATE OF HIMACHAL HIMALAYAS

Himalayas show a vast variety of climates throughout its mountain ranges. Both winter westliers and summer monsoons are barred by these mountain ranges. Summer monsoons last for eight months from March to October in eastern Himalayas, two months in July and August in western Himalayas and four months from June to September in central Himalayas [3]. The monsoon proceeds along Brahmputra River to Tibetan Plateau, but rarely shows in Karakoram mountain ranges [5], [14], [9]. Outside the polar regions, Higher Himalayas comprises of highly glaciated areas [12], [4] and snow and ice melt of summer monsoons of these glaciers basins contribute about 70% flow for Ganges, Kabul and Indus rivers [7], [17], [2] and also for dry season these glaciers serve the same [1]. Western Himalayas feed most of the irrigation lands downstream [19].

Himachal Himalayas exhibits variation of temperatures from low being 2.14 and maximum being 31.92C (Fig. 2, 3).

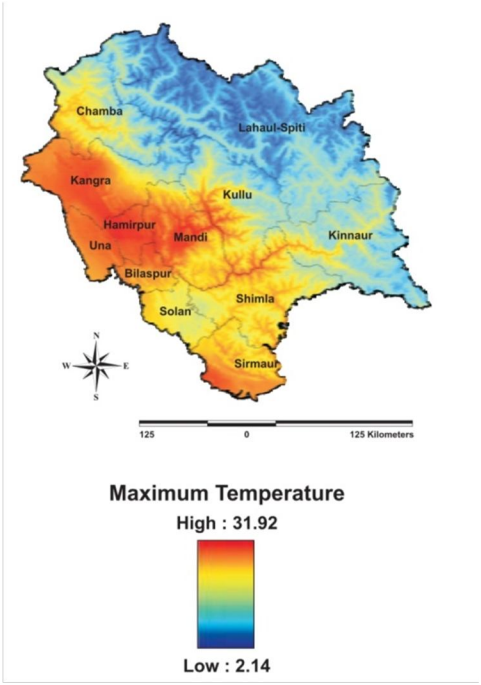


Fig. 2 Temperature variation map of Himachal Himalayas (source:ibid)

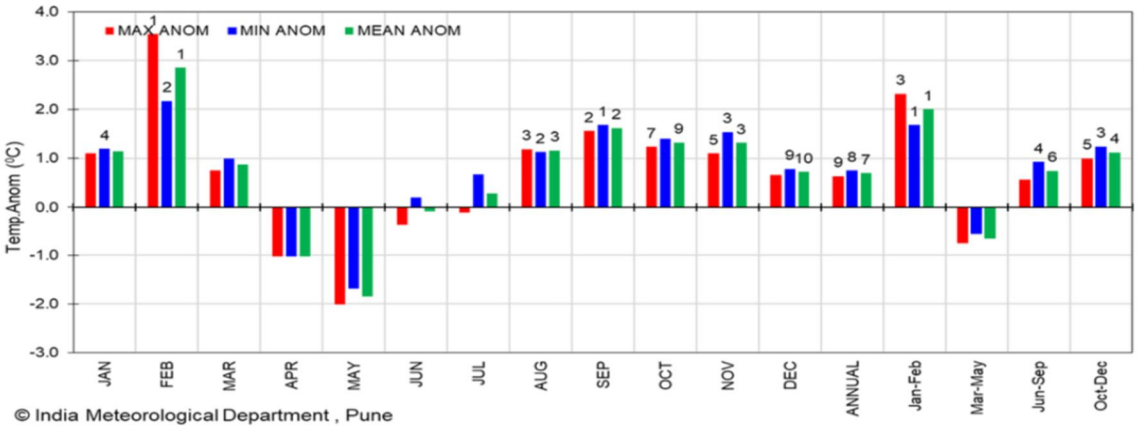


Fig. 3 Monthly temperature anomalies of state -2023

A significant variation in terms of increasing temperature trend is observed in state as we study the time series for period 1901-2023 as shown in Fig. 4. The state is experiencing 0.06 degrees Celsius rise in annual mean maximum temperature per year for about two decades. Frequent heatwaves are increasing per year with a rate of 0.21 per year.

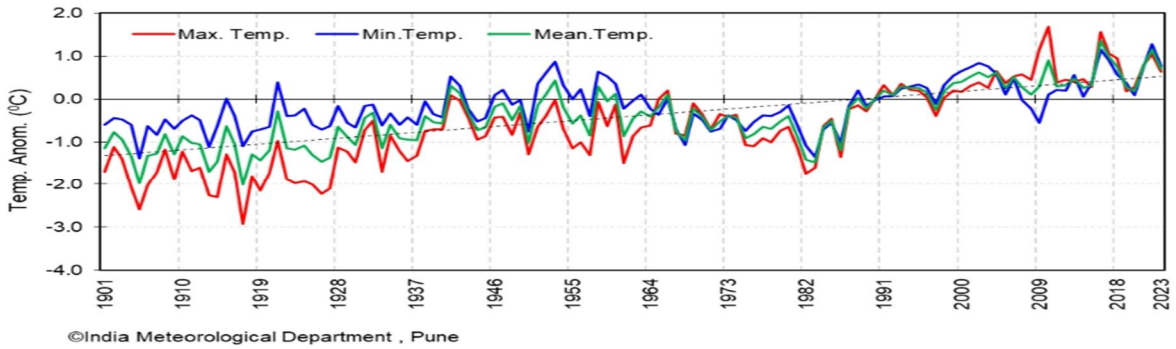


Fig. 4 Temperature anomalies of Himachal Himalayas (1901-2023)

Similarly, rainfall also show variation from 50mm in Lahaul Spiti to over 3,000 mm in Dharamshala and the state receives about 1,251 mm annual rainfall (Fig. 5,6,7 ibid). In Himachal Himalayas, a significant decreasing trend for annual rainfall is observed. For about two decades the state is experiencing 3% decrease in monsoon rainfall.

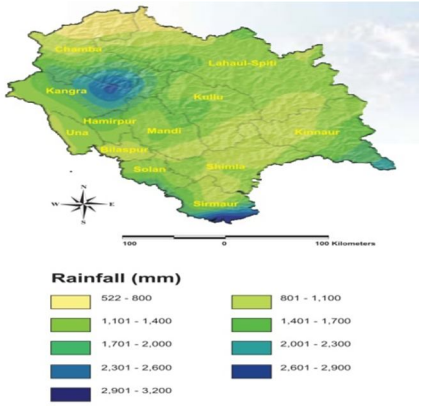


Fig. 5 Annual rainfall map of Himachal Himalayas

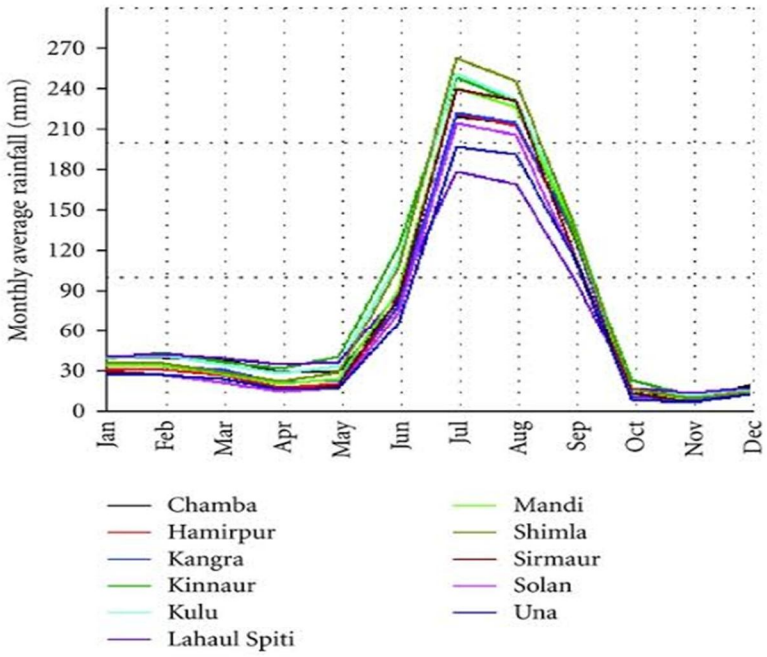


Fig. 6 Monthly rainfall graph of Himachal Himalayas

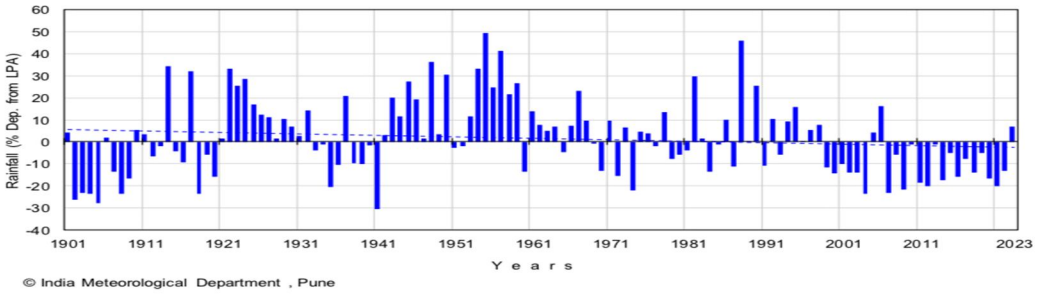


Fig. 7 Rainfall anomalies of state (1901-2023)

Precipitation in state declines from south to north and west to the east. During winters from December to March, about 3 meters of snow is experienced. All these temperature and rainfall variations are due to varied altitudes of the region as shown in Fig. 8. Southern parts of state are suffering more temperature variations while northern high- altitude regions are witnessing a slow change.

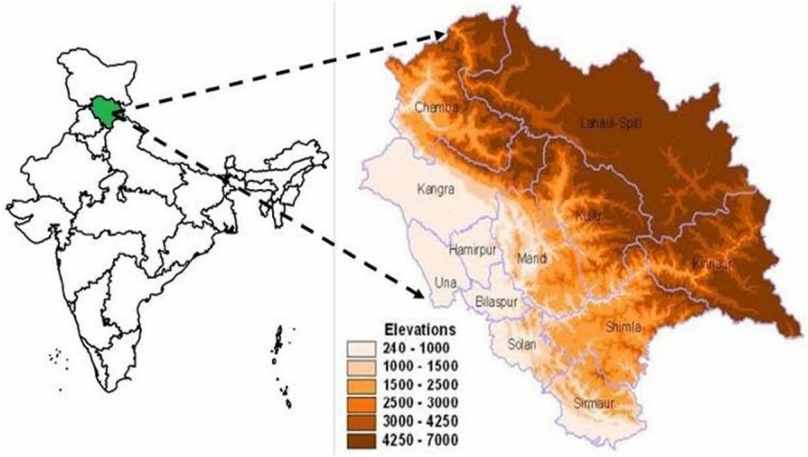


Fig. 8 Elevation map of Himachal Himalayas

III.AGRO- ECOLOGICAL ZONES

The state is sub-divided into 9 agro-ecological zones and these zones separate the state into sets of similar potentials of elevation and precipitation. These zones form a strong base for sustainable natural resource management and agricultural planning (Table 1).

TABLE 1
AGRO- ECOLOGICAL ZONES OF HIMACHAL

Sr. No.	Zones	Districts	Area per square km	Elevation	Rainfall
1	Zone 1.1	Kangra, Una, Hamirpur, Bilaspur	8201	240-1000m	1600mm
2	Zone 1.2	Kangra, Sirmaur	2059	240-1000m	1600mm
3	Zone 2.1	Sirmaur, Solan, Mandi	3770	1001-1500m	1500mm
4	Zone 2.2	Mandi, Shimla	894	1001-1500m	1500mm
5	Zone 3.1	Shimla, Mandi, Chamba, Kullu	8207	1501-2500m	1500mm
6	Zone 3.2	Chamba, Kangra	1010	1501-3250m	1500mm
7	Zone 4.1	Mandi, Chamba, Shimla, Kullu, Kinnaur	4616	2501-3250m	
8	Zone 4.2	Chamba, Kullu, Kinnaur, Lahaul- Spiti	7003	3251-4250m	
9	Zone 4.3	Kinnaur, Lahaul- Spiti	19890	>4250m	

IV. GLACIERS AND WATER RESOURCES OF HIMACHAL HIMALAYAS

According to a recent study, there are about 2,554 glaciers in state and covers an area of 4160 square km (Table 2). These glacial ice and snow cover feeds the perennial rivers and make their watersheds (Fig. 9, Table 3). These rivers feed agricultural, grazing and forest lands downstream and provides water for energy, irrigational, domestic and industrial purposes.

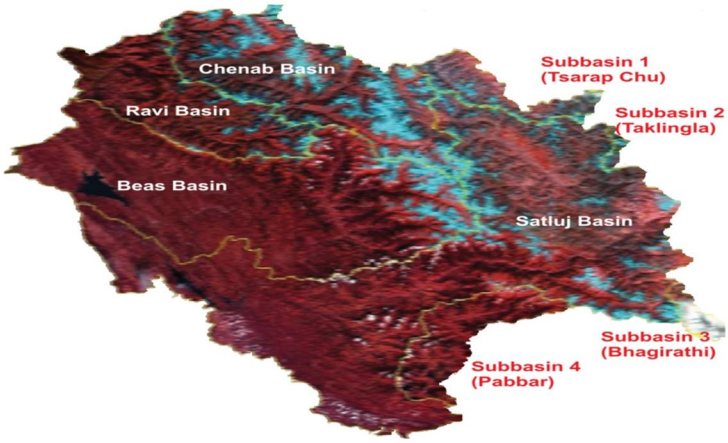


Fig. 9 River basins of Himachal Himalayas

TABLE 2
THE ESTIMATED VOLUME OF GLACIERS IN HIMACHAL HIMALAYAS

Sr. No.	River Basin	Number of Glaciers	Area in square km	Ice reserves in square km
1	Satluj	945	1217	94.0
2	Chenab	681	1704	187.0
3	Beas	358	758	76.0
4	Tsarap Chu	250	163	8.0
5	Ravi	198	235	17.0
6	Taklingla	55	32	1.4
7	Bhagirathi	43	43	2.4
8	Pabbar	24	06	0.2
	Total	2554	4160	387.0

TABLE 3
RIVER SYSTEMS OF HIMACHAL HIMALAYAS

Sr. No.	River System	Catchment Area per square km
1	Satluj	20,398
2	Beas	13,663
3	Chenab	7,850
4	Yamuna	5,872
5	Ravi	5,528
6	Indus	1,450
7	Markanda	360
8	Ganga	290
9	Ghaggar	262
	Total	55,673

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V. FUTURE IMPACTS OF CLIMATE CHANGE

1) Increased frequency of precipitation on heavy scale has increased runoff and therefore groundwater recharge is reduced. This has also added a vast amount of sediments to stream channels due to which agricultural lands are suffering in terms of crop loss and soil erosion. Hydropower plants are facing troubles and continuation of sediment loading will lead to shut down of many hydropower projects in near future.
2) Increased heavy rainfall intensity is triggering flash floods which ultimately damage and disrupt settlements, crops, agricultural lands, infrastructures, roads and human life.
3) Reduced snowfall trends are increasing winter runoffs and reducing river flows during dry seasons. This may induce drying of many small tributaries and also springs and perennial water resources can reduce. This may lead to shortage of water for agricultural lands even during summers and can trigger soil erosion due to high rainfalls during winters.
4) Increasing temperatures have caused early snow melts. This will lead to reduce summer flows and will increase spring flows. Croplands will suffer perennial water channels and reduced summer flows.
5) Varying rainfall patterns can induce erratic stream flow patterns that affect non- irrigated crops. Increased variability of rainfall will reduce hydro-power production.
6) Fluctuating climate will increase risks of water shortage crisis and even drought conditions that will further affect hydropower generation, reduction of water availability for irrigation and other water schemes in state. Rainfed cropping will be impacted drastically.
7) Increasing temperatures will lead to increase in temperature of lake and rivers that will severely affect lives within theses water resources. Aquatic ecosystems will face drastic changes in terms of balance between phytoplankton and zooplanktons. Increasing temperature of water resources will promote bacterial growth.
8) Fluctuating climates and increased temperature are drastically affecting glacier volumes. Glaciers are reservoirs of water and are shrinking at notable speeds and will lead to increased water variability in stream channels, reduced water supplies for domestic as well as industrial use, disruption to ecosystems, disruption to irrigation schemes and will increase risks of natural disasters like Glacial Lake Outburst Floods (GLOFs), landslides and Albedo effects due to exposure of darker land surfaces and that will again contribute to global warming. Glacial retreat will affect tourism industry of state as well and this will lead to directly affecting state's economy in near future.

VI. ADAPTATION STRATEGIES

The proposed climatic adaptation and strategic roadmap is shown in Table 4.

TABLE 4
STRATEGIC FRAMEWORK

Sr. No.	Key Areas	Adaptation Strategies
1	Catchment Planning and Management	Soil and water conservation Ground water management Flood management Identify issues and options in sub- catchments for adaptation approaches like economic, environmental, social and technical assessments. Environmentally sustainable development
2	Agricultural Planning and Management	Insurance Improved agricultural and irrigational techniques Water harvesting techniques New seed verities according to weather shifts Agro-forestry Adapting perennial crops instead of annual crops Adjusting cropping schedules Improvement in water supply and irrigation efficiency. Ground water management Flood management

3	Water Resources Data and Information Systems	Establishing Integrated Data and Information unit Gathering information from central and state bodies, international agencies and research institutes Modern computerized information systems
4	Disaster Preparedness	Sustainable land use and urban drainage planning Contingency plan preparedness to meet and reduce water disaster situations Identification of increased vulnerability and risks to communities GLOF monitoring and early risk assessments
5	Hydro-power Sector Planning and Management	Check dams and storage units to reduce sediment levels Optimizing of cascade dams Flood management
6	Rural Employment	Review opportunities for off-farm income sources Encourage and support investments in crafts, rural enterprises, tourism etc.
7	Policies and Regulations	Carbon pricing Emissions trading schemes Emission reduction regulation
8	Individual Actions	Plantation drives Support climate friendly business Adapting resource conservation practices Minimize resource consumption Support RRR i.e. Reduce, Reuse and Recycle Adopting safer and cleaner technologies Promoting and adapting public transport , electrical vehicles and cycling Reducing food wastes Shifting to renewable sources like hydropower, wind and solar power to reduce greenhouse effects

VII. CONCLUSION

Global warming is changing Cryosphere in terms of glacial retreat and climatic changes. Impacts to these threats are quite noticeable and alarming. Himachal Himalaya is the youngest arcuate mountain belt whose snow cover and nine river systems provide water for irrigation, drinking and hydro power generation and also contribute to GDP and other environmental services of the inhabitants of these river basins. A significant climatic variation is observed in recent years in terms of global warming which in turn causing glacial retreat, shrinkage of river catchment areas, varied patterns in rainfall and also agriculture in study area. Increased frequency of heavy precipitation, groundwater recharge disturbance, flash floods, GLOFs, drying of springs and small tributaries, early snow melt, water crisis and disturbance to lives are secondary and even more drastic effects of climatic changes in the region. Crops patterns are disturbing due to rising temperatures of Himachal Himalayas. Lack of awareness regarding climatic changes in the region is also a major setback. Proper and strategic implications are needed to reduce and mitigate upcoming threats due to climatic shifts. A quite damage to Himalayan environment has already been done and urgent actions and awareness are needed to prevent these assets from diminishing.

VIII. ACKNOWLEDGMENT

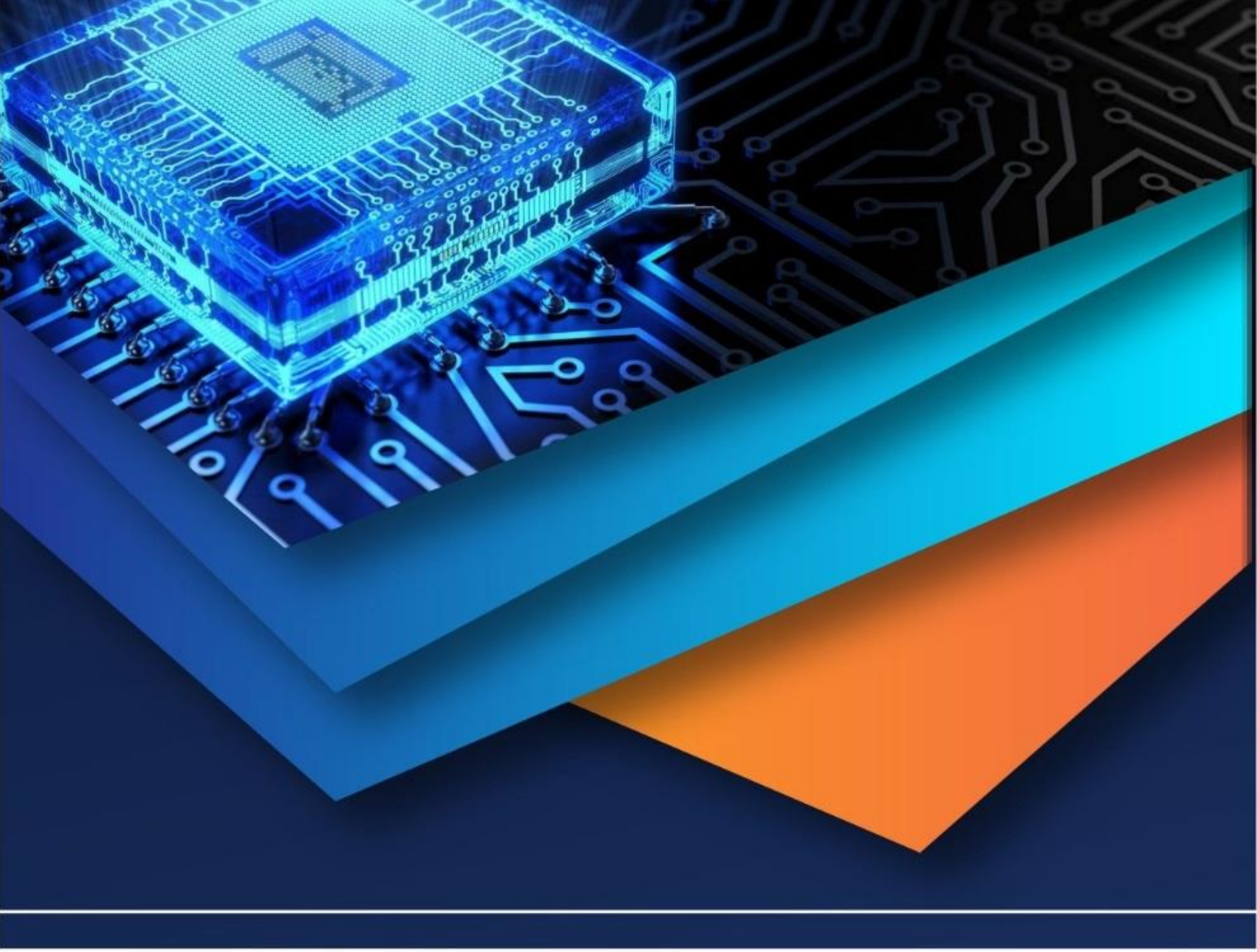
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