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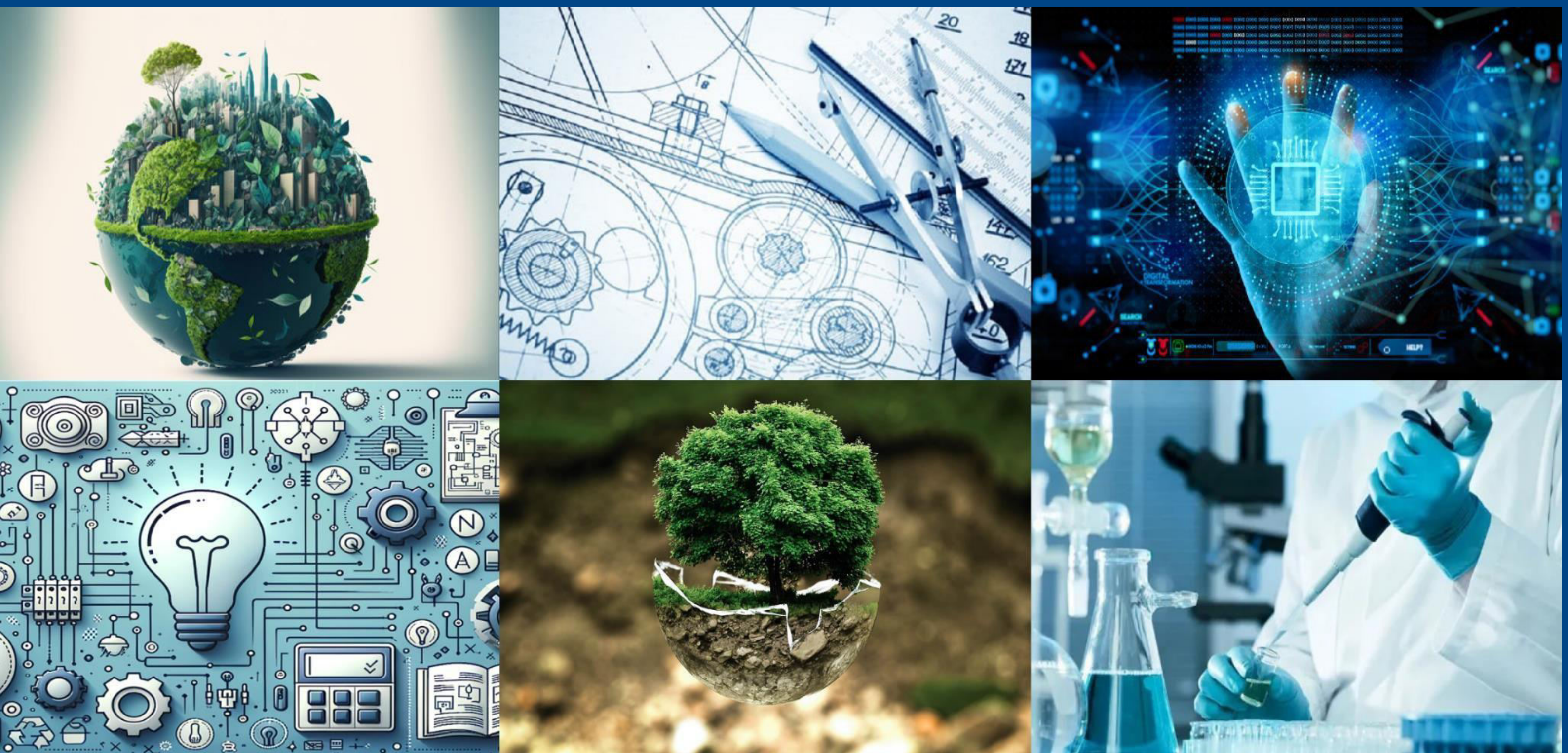

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Impact of Climate Change on Future Flood Hazard Evaluation Under Distinct Shared Socioeconomic Pathway Scenarios of Mondego River Basin, Portugal

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ABSTRACT: Flooding represents a major and escalating global threat, with its frequency and severity projected to intensify due to global warming. As communities worldwide grapple with the consequences of climate change, there is a pressing need for highly detailed and localized risk assessments to inform effective adaptation strategies. This study addresses this need by evaluating the evolving flood hazard within Portugal's Mondego River basin under two contrasting climate change scenarios: SSP2-4.5 (an intermediate pathway) and SSP5-8.5 (a high-emissions pathway). The analysis projects risks for four key time horizons throughout the 21st century: 2025 (current), 2050 (mid-century), 2075 (early-end century), and 2100 (end-century). To map the flood hazard, the research employed a GIS based Multi-Criteria Decision Making (MCDM) methodology known as Weighted Overlay Analysis (WOA). This technique synthesizes various contributing factors such as rainfall, topography, and land use to classify the basin into five distinct zones of flood hazard susceptibility: very low, low, moderate, high, and very high risk. Under the SSP2-4.5 scenario, flood hazard zones remain dominant in the near future (2025–2050), accounting for approximately 37–39% of the total area, but this proportion gradually declines to about 22% by the end of the century (2100). In contrast, the SSP5-8.5 scenario exhibits a temporary reduction in very high flood hazard areas around mid-century (2050), followed by a pronounced increase of nearly 28% by 2100. Overall, projections under SSP2-4.5 suggest a redistribution of extreme flood risk toward moderate hazard categories, indicating a relative attenuation of severity, whereas SSP5-8.5 projections point to persistent and intensifying high-severity flooding, highlighting the escalating influence of aggressive climate forcing toward the end of the century. The resulting hazard maps reveal a dynamically shifting landscape of risk, directly influenced by the climate scenario and time period. The findings show significant variations in the percentage of land area assigned to each risk category, underscoring how future socioeconomic choices and emission levels will directly shape regional vulnerability.

KEYWORDS: MIROC6, SSP, Climate change, Flood Hazard Map, WOA.

I. INTRODUCTION

Cloud is an emerging technology and cloud based storage is the newly adopted idea that facilitates users not only to upload data to the web but also allows instant accessibility to available resources and share data with anyone at any point of time. But Cloud is a technology that creates a challenge for the person who is investigating and finding out the forensic evidences that may help in the forensic analysis as data stored on cloud can be accessed from anywhere and from any system and very little amount of traces are left behind. Globally, floods accounted for about 43% of all natural disasters and 47% of climate-related disasters, impacting nearly 2.3 billion people between 1995 and 2015 [4] and causing economic losses exceeding USD 1 trillion between the years 1980 and 2013 globally [5]. Human activities have led to a substantial rise in greenhouse gas emissions, driving continuous climate change and exerting harmful impacts on river ecosystems [6,7]. In recent decades, both the magnitude and frequency of floods have notably increased worldwide [8,9,10]. This increase is largely related to climate change, which intensifies and raises the frequency of extreme meteorological events [11]. Climate change has a significant impact on the probability and intensity of these extreme events, including intense precipitation [12], which directly affects land use since they influence the terrain's capacity to absorb and drain water, modifying river flow, and causing significant alterations in global hydrological regimes [13,14].

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Extreme precipitation events are particularly concerning because of their unpredictable and destructive nature, often triggering sudden and intense floods that overwhelm infrastructure and result in substantial material damage [15,16] therefore, to address these risks, it is crucial to conduct a complete analysis of extreme rainfall due to climate change and the impact it will generate in the future. It is crucial to recognize that, in the future, many countries across the globe are likely to experience more severe floods than those observed at present, primarily as a consequence of climate change [17, 18,19] and this is the reason why many authorities, engineers, and researchers are focusing their attention on quantifying the influence of climate change on the hazards and risks of future floods, in order to prevent and develop strategies that serve as climate change adaptation and to propose mitigation strategies [20,21,22]. Nowadays, mathematical models, hydrological simulation, and runoff prediction have become more relevant for hazard management, risk assessment, and disaster mitigation caused by floods [23,24,25], becoming fundamental tools that contribute to research in modern hydrological engineering [26,27,28].

On the other hand, due to the various negative effects caused by climate change, the need has arisen to have climate models that better understand the climate system to prevent its future evolution; for this reason, the Working Group on Coupled Modelling (WGCM) of the World Climate Research Program (WCRP) developed the Coupled Model Intercomparision Project (CMIP) approximately 30 years ago [29]. Over time, several coupled model intercomparison projects have been developed—ranging from CMIP1, CMIP2, CMIP3, and CMIP5 to the most recent CMIP6—each playing a crucial role in advancing climate modeling and providing data that underpins the global assessment reports of the Intergovernmental Panel on Climate Change (IPCC) [30]. At present, the most recent CMIP6 model is available and will be the focus of attention, as it incorporates Shared Socioeconomic Pathways (SSPs) that provide more advanced climate change projections along with enhanced spatial and temporal resolutions, enabling more accurate simulation of extreme climate events [31].

In light of the above research review, the present study seeks to identify and project flood-hazard prone areas in the future under changing climate conditions. The analysis is carried out using two Shared Socioeconomic Pathway (SSP) scenarios: SSP2-4.5, which represents a stabilization pathway with moderate greenhouse gas emissions, and SSP5-8.5, which reflects a fossil fuel–driven trajectory with high emissions. This investigation is particularly relevant to the Mondego River basin, where large riverine floods frequently occur as a result of intense precipitation events. Such floods have historically led to severe social, economic, and environmental consequences, highlighting the urgency of assessing future flood risks to inform effective adaptation and mitigation strategies.

II. MATERIALS AND METHODOLOGY

Study Area: The Mondego River is the longest river located wholly in Portugal. The total area of its basin is 6597 km^2. The source of the Mondego is in Serra da Estrela which is highest mountain range in mainland Portugal, with the highest point being nearly 2000 m above sea level, and the course of the river runs 258 km until it reaches the Atlantic Ocean at Figueira da Foz. This river flows through three districts in the central region of Portugal, namely, Guarda, Viseu and Coimbra. It is a narrow river in the upper part and widens in the lower part after crossing the city of Coimbra as shown in figure 1.

Open-source spatial datasets, such as the Digital Elevation Model (DEM) and Land Use/Land Cover (LULC) data, were utilized for the preparation of various thematic layers required for flood hazard mapping. Precipitation data, essential for projecting future flood scenarios under changing climate conditions, were obtained for multiple time periods, including the current (2025), early (2050), mid (2075), and late 21st century (2100). These datasets were analyzed under two Shared Socioeconomic Pathway (SSP) scenarios, as outlined in Table 1, to predict potential flood hazards. Furthermore, based on an extensive review of relevant literature and consultation with domain experts, six key criteria were identified and selected as the primary factors influencing flood hazard mapping. These criteria form the foundation for developing a comprehensive and scientifically robust flood susceptibility model aimed at understanding future flood risks

Methodology

The study focused on flood hazard mapping by utilizing various datasets and following a systematic sequence of methods. The research aimed to develop a Weighted Overlay Analysis (WOA) model, integrating Remote Sensing and GIS techniques within a geospatial environment using ArcGIS 10.8.1. The model was constructed using six key flood-influencing physical variables: elevation, slope, rainfall, LandUse/LandCover (LU/LC), distance from rivers, and flow

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length. The primary objective was to create a flood hazard zone map that categorizes areas into very high, high, moderate, low, and very low flood hazard zones.

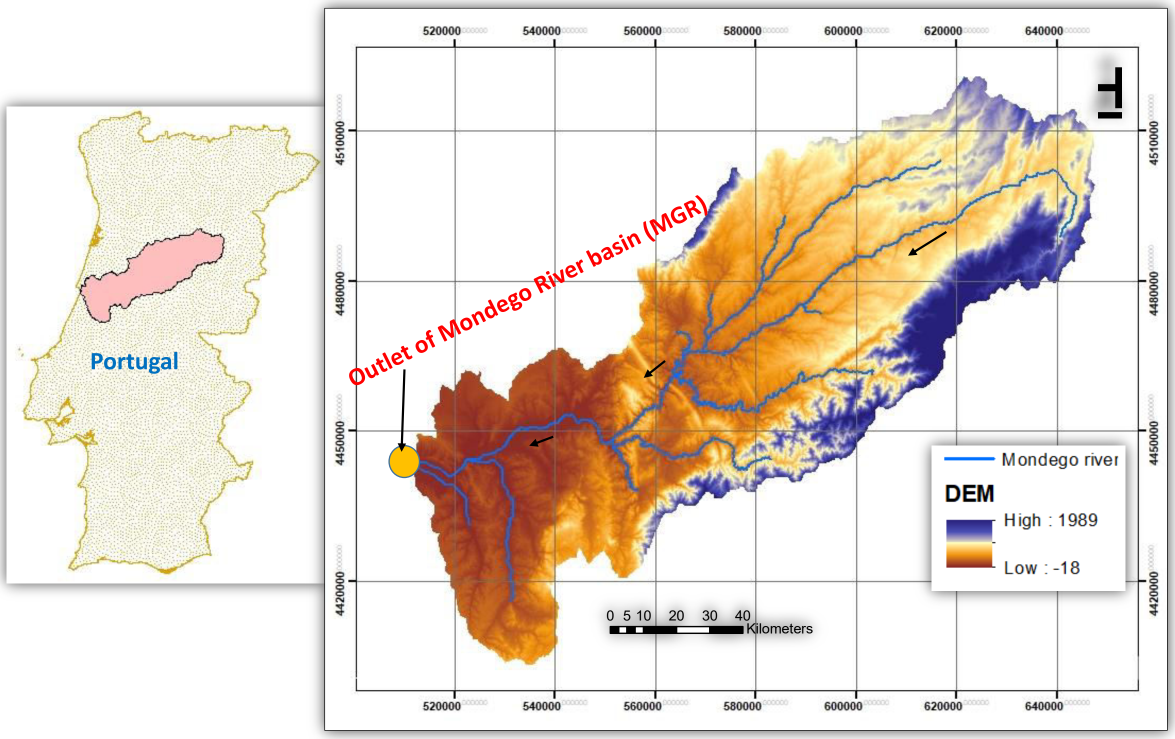

Figure 1: **Location map of Mondego River Basin (Portugal)**

The study employed a Multi-Criteria Decision-Making (MCDM) approach, specifically the Weighted Overlay Analysis, to calculate the relative importance of each factor, ensuring an accurate and meaningful outcome [32]. The MCDM-based WOA model effectively quantified the weightage of the six selected factors, helping to determine the potential of each element in contributing to flood hazards. The detailed discussion on this process is provided below. The methodology applied as shown in flow chart [Fig.2]

Table 1. Description of data sources used for processing flood hazard mapping criteria

Sl.No	Data Type	Description	Source
1	DEM	SRTM DEM (30 m)	https://www.earthdata.nasa.gov
2	Precipitation	NEX-GDDP CMIP6 MIROC6	https://nex-gddp-cmip6.s3.us-west-2.amazonaws.com/index.html
3	Land use Land cover	ESRI-Sentinel 2A	https://livingatlas.arcgis.com

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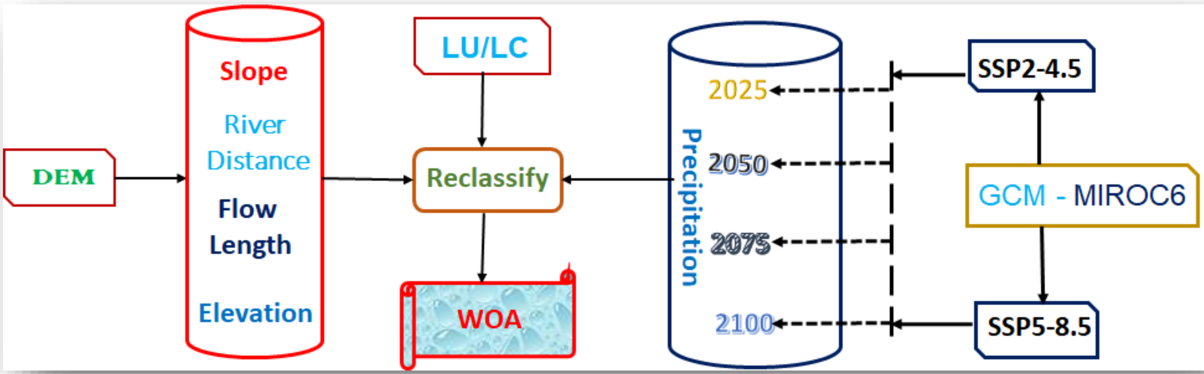

Figure 2: Flow chart of methodology

Weighted Overlay Analysis (WOA) Method

WOA is one of the method derived from a Multi-Criteria Decision Making (MCDM) approach. The concept of Weighted Overlay Analysis (WOA) for flood hazard mapping has been developed and refined by various researchers over time. This method laid the groundwork for WOA by providing a systematic approach to assigning weights to different factors. Weighted Overlay Analysis is a widely used method in Geographic Information Systems (GIS) for combining multiple spatial datasets to assess and map different scenarios, such as flood vulnerability, land suitability, and environmental risk. This approach is particularly effective in situations where multiple factors contribute to a certain outcome, and it helps to determine the relative importance (or weight) of each factor.

The Weighted Overlay Analysis is a decision support tool used to determine the weights and ranks of various parameters for identifying flood-vulnerable zones (FVZ). In this study, the WOA model was developed using six thematic layers, which were applied to categorize different flood hazard zones. The model assigns varied weights to each parameter based on its relative importance in contributing to flood risk. This can be done through expert judgment, statistical analysis, or a combination of both. Table 3 provides the specific weightage assigned to each variable in the analysis.

Identifying and selecting the relevant factors or criteria that influence the outcome. For flood hazard mapping, these might include elevation, slope, land use/land cover, distance from rivers, precipitation, flow length etc. The weighted criteria are combined using GIS tools, resulting in a composite map that reflects the overall scenario (e.g., flood hazard zones). The final map highlights flood areas of very high, high, moderate, low and very low risk zones.

The specific application of WOA in GIS is a result of integrating these MCDM principles with spatial analysis capabilities, particularly through software like ArcGIS developed by ESRI. The methodologies were further refined by various researchers and practitioners in the field of environmental science, urban planning, and disaster management. For modern GIS-based WOA, Esri's development of tools within the ArcGIS environment has been instrumental in popularizing and standardizing the approach. However, no single individual is credited with inventing WOA in its GIS application; it is an evolution of MCDM principles applied within the context of spatial analysis.

Table 2**:** Numerical weightage of each variables

Name of variable	Weightage
Slope	40
Flow length	5
Precipitation	15
River distance	5
LU/LC	5
Elevation	30

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WOA Model Influencing Factors

The WOA model is influenced by six key factors: watershed slope, stream flow length, precipitation grid data, river proximity, land use/land cover, and topographic elevation within the watershed. Each of these factors plays a significant role and is described in detail below. The reclassified GIS layers are shown in Figure 3.

Slope: In the hydrological study, slope plays a vital role to regulate the flow of surface water, and slit is one of the most important topographic factors for such studies [33]. Land surface slope is one of the effective factors in floods lower the slope higher is the intensity of flood and the higher the slope lower is the intensity of flood occurrence. The slope of a channel in a region is having a direct relationship with the flow velocity [34]. When the river slope increases then the flow velocity in the river also will increase [35]. The slope has a direct relation to infiltration. An increase of the surface slope reduces the infiltration process but increases the surface runoff; as a result, in the regions having a lower surface slope, an enormous volume of water becomes stagnant and causes a flood situation. The slope map has been created from the Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) 30 m resolution and reclassified as shown in figure 3 A.

Flow length: Flow length is a key criterion in flood hazard mapping, representing the distance that water travels from a point on the terrain to the nearest drainage outlet, such as a river or stream. It helps in understanding surface runoff dynamics, with shorter flow lengths indicating quicker water accumulation in drainage outlets, potentially increasing flood risk. Calculated using Digital Elevation Models (DEMs) in GIS software, flow length is integrated with other factors like slope and land use to create comprehensive flood hazard maps. This analysis aids in identifying areas most vulnerable to flooding and informs flood risk management strategies.

Precipitation – GCM: Precipitation data were downloaded in 'netCDF' format for four target years—2025, 2050, 2075, and 2100—under two Shared Socioeconomic Pathway (SSP) scenarios, namely SSP2-4.5 and SSP5-8.5. These datasets were obtained from the MIROC6 Global Climate Model (GCM) through the NASA Earth Exchange-Global Daily Downscaled Projection (NEX-GDDP) web portal. The data were used to assess future flood hazard risk zones within the Mondego River basin in Portugal. Following acquisition, the 'netCDF' files were processed and converted into grid format specifically clipped to the Mondego River basin boundary. Each precipitation dataset for the respective years was further classified into five distinct precipitation intensity classes to facilitate spatial analysis. As a result, a total of eight gridded precipitation map layers were generated four for SSP2-4.5 (Fig. 4 A1, B1, C1, D1) and four for SSP5-8.5 (Fig. 5 E1, F1, G1, H1). These layers serve as critical inputs for the Weighted Overlay Analysis (WOA) method, enabling the development of comprehensive flood hazard risk maps to predict and visualize future flood-prone zones under varying climate change scenarios.

River Distance: Distance from the river (River Distance) is one of the most important factors in flood hazard mapping. As the distance increases, the elevation and slope becomes higher. Also, Stream is generally the lowest point of that particular region. As a result of this, areas far from the river are having lower vulnerability of flood occurrence. During floods, river banks get overflowed and submerge the dry land nearby the river. In this study we have classified distance from river in to five classes from very high, high, moderate, low, and very low as shown in Fig.3 D. Lesser the distance from the river more is the flood vulnerability occurrence and more is the distance from the river lesser is the vulnerability.

Landuse/Landcover: Land Use-Land Cover (LU-LC) is the primary driver in changing the landscape of a specific area. LULC map has been downloaded from GlobCover web portal and are classified in to eleven classes, then further reclassified into five classes on the bases of weights such as class one waterbody having area of 51 km^2, second class forest having area of 3022 km^2, third class agricultural land having area of 336 km^2, fourth class Built-up having area of 1122 km^2, and fifth class rangeland/snow having area of 2119 km^2. The study highlighted that the class second, fourth and fifth are regarded as highly susceptible, while class first and third are least vulnerable to flood as shown in Fig.3 E.

Elevation: In the study of flood hazard mapping, according to the expert's opinion, the elevation of an area is the most important factor for controlling the flood vulnerability [36]. Reasons located in higher elevation generally have the lower potentiality to be flooded, whereas lower elevated regions are having higher vulnerability potential. Water is having the tendency to flow towards the lower region from a higher region; and therefore, low elevated regions with a

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flat surface area have a higher potential of flood occurrences [37].The elevation of the study area ranges from -18 to 1989 m and reclassified into 5 classes as shown in Fig. 3 F.

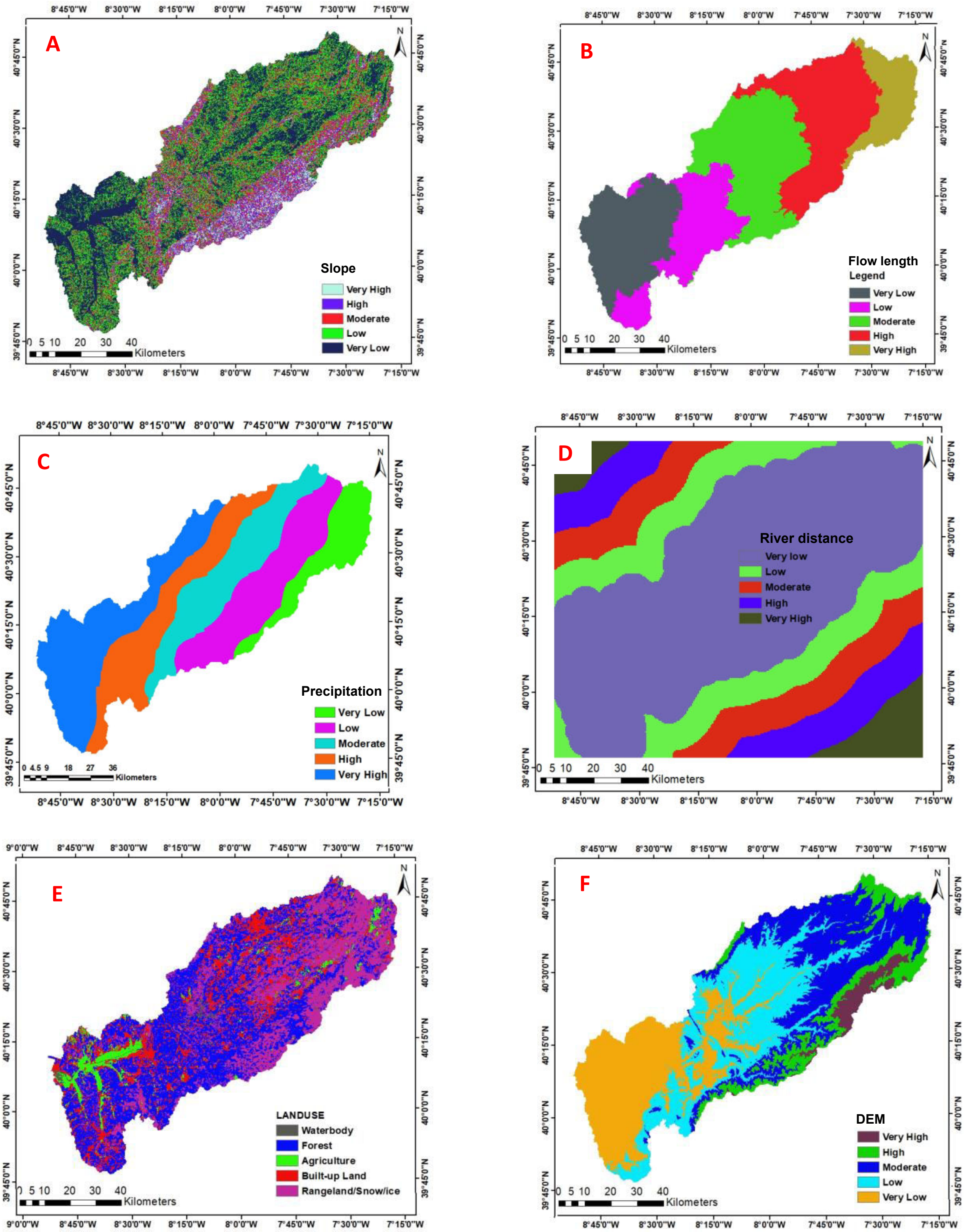

Figure 3: Reclassified GIS Layers for Application of Weighted Overlay Analysis (WOA) Method

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III. RESULTS AND DISCUSSIONS

The main objective of this study is to identify and map flood hazard zones in the Mondego River Basin, Portugal, using precipitation data from the MIROC6 Global Climate Model (GCM) under two Shared Socioeconomic Pathway (SSP) scenarios: SSP2-4.5 (medium stabilization) and SSP5-8.5 (high emissions). The analysis is carried out for four time periods: 2025, 2050, 2075, and 2100. A Weighted Overlay Analysis (WOA), part of the Multi-Criteria Decision-Making (MCDM) approach, is used to compute flood hazard zones, and categorized into Very Low, Low, Moderate, High, and Very High. Six GIS layers—Slope, Flow Length, Precipitation, River Distance, Land Use/Land Cover, and Elevation—are reclassified and assigned weightages of 40%, 5%, 15%, 5%, 5%, and 30%, respectively. The analysis is performed using ArcGIS 8.1, generating flood hazard maps for each scenario and time frame. These results provide insights into the spatial variation of flood risks under different climate change and discussed in the following paragraphs under different scenarios as follows.

Scenario 1: Simualtion Results of Emission SSP2-4.5

The flood hazard zone analysis under the SSP2-4.5 climate change scenario shows significant spatial and temporal variations in vulnerability levels from 2025 to 2100. In 2025, the flood-prone area is predominantly categorized under the very high flood hazard zone (37.3%), followed by the high hazard zone (31.5%), indicating severe existing risks in a large portion of the region. Moving into 2050, the dominance of the very high (38.5%) and high hazard zones (33.9%) continues, highlighting that the conditions may worsen due to climatic intensification and hydrological shifts. However, a crucial transition is observed beyond mid-century. By 2075, the proportion of very high flood hazard areas declines sharply to 24.2%, and further reduces to 21.7% by 2100, indicating that some extreme-risk locations are redistributed into lower hazard categories. Correspondingly, the moderate flood hazard zone increases significantly, rising from 16.4% in 2025 to 22.0% in 2075 and reaching 24.3% by 2100. This suggests an expansion of moderately vulnerable regions, likely driven by increased rainfall variability, flood routing changes, and rapid land-use alterations. The low flood hazard class also shows a gradual rise up to 2075 (14.0%) before slightly declining in 2100 (13.1%). Meanwhile, the very low-risk category initially decreases from 4.7% in 2025 to 2.6% in 2050 but improves in later years, reaching 7.7% in 2100, implying local improvements in flood resilience or the impact of adaptive flood management measures. Overall, the projections indicate that although extremely flood-prone areas may reduce in magnitude**,** a larger area transitions into moderate to high flood vulnerability, reflecting continuing risk escalation under future climate conditions**.** These trends clearly emphasize the need for proactive hydrological planning, disaster-management strategies, and sustainable catchment development to mitigate the evolving flood hazards in the study area.

Table 3: Flood areas covered in the Mondego River Basin for different years of SSP2-4.5

Flood Hazard Zone	**Flood Hazard Area covered in Km^2 of emission scenario SSP2-4.5**			
	Year-2025 (Fig.A)	Year-2050 (Fig.B)	Year-2075 (Fig.C)	Year-2100 (Fig. D)
Very Low	313	169	535	505
Low	664	737	924	867
Moderate	1083	909	1450	1600
High	2075	2239	2094	2196
Very High	2462	2543	1594	1429

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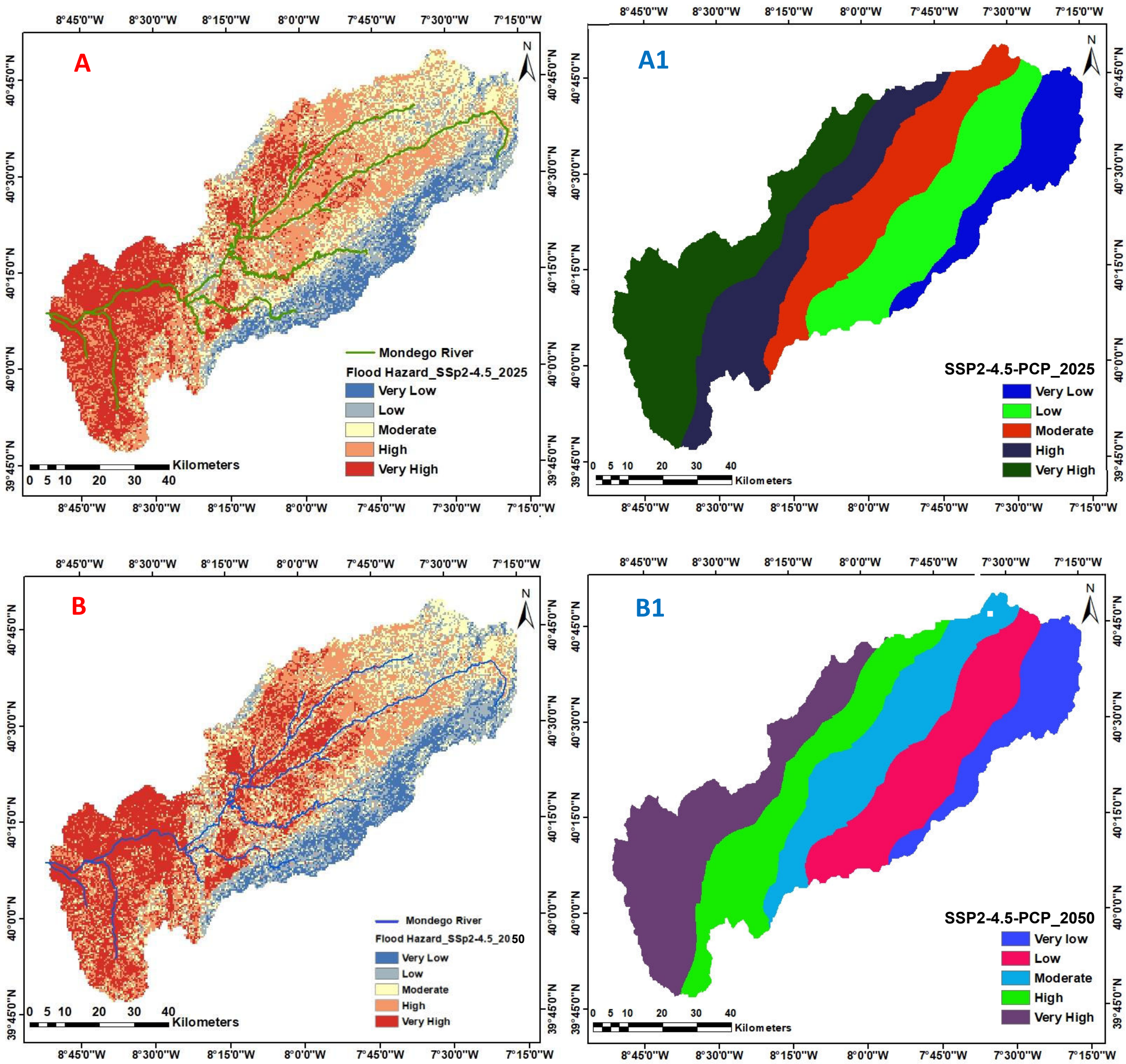

The Low and Very Low hazard zones show gradual decreases, with the Low hazard area shrinking from 885 km² to 798 km², while the Very Low hazard area remains relatively stable, ranging between 476 km² and 511 km². Overall, these trends suggest that climate change impacts will intensify flood hazards, with a substantial increase in extreme flood-prone areas and a reduction in low-risk zones, emphasizing the urgent need for adaptation measures and proactive flood management strategies in the Mondego River Basin.

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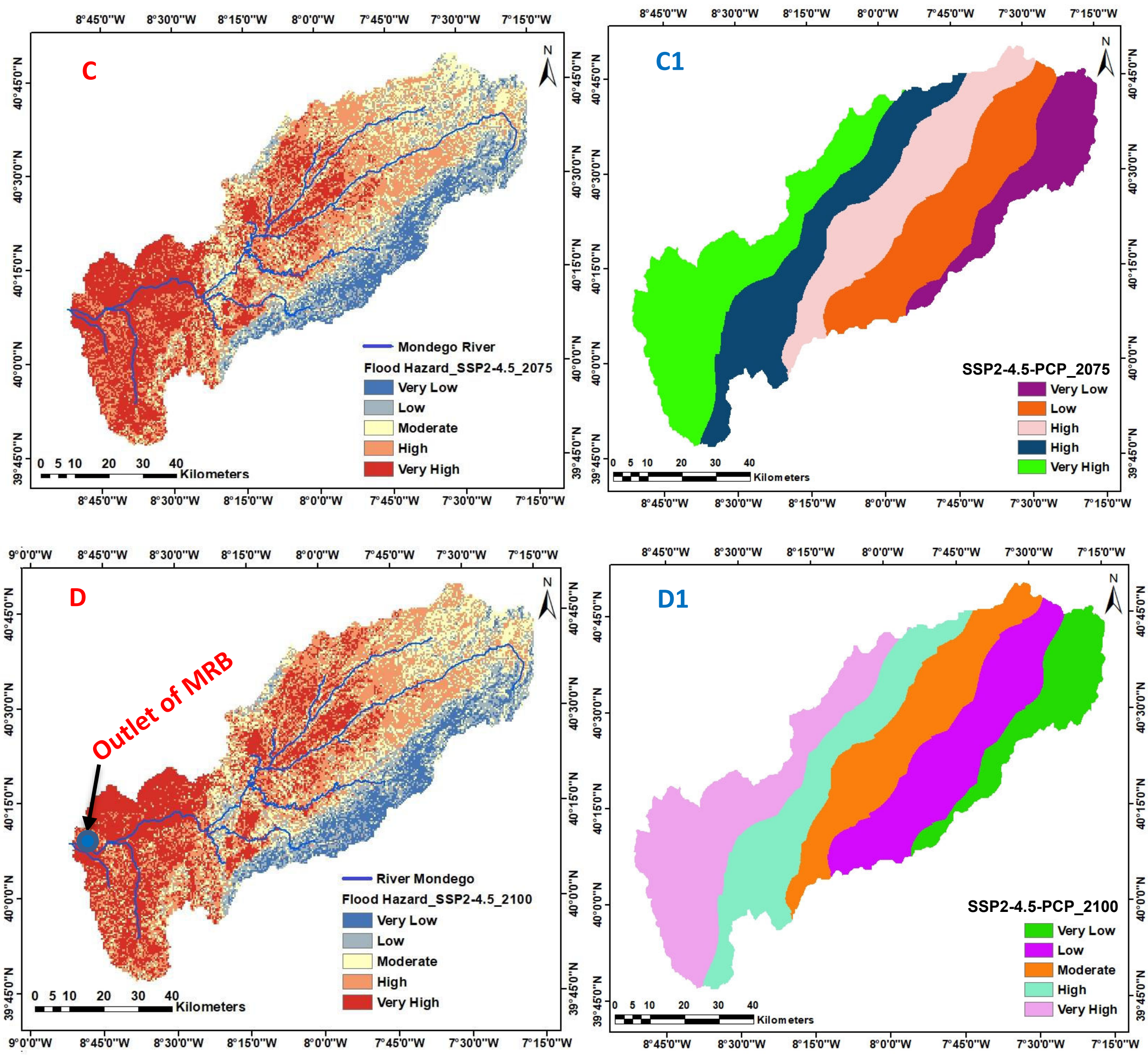

MRB: Mondego River Basin

Figure 4: Flood Hazard maps for 2025 (A), 2050(B), 2075(C) and 2100(D) and corresponding Precipitation classes (A1), (B1), (C1), (D1) for emission scenario of SSP2- 4.5

Scenario 2: Simualtion Results of Emission SSP5-8.5

Under the SSP5-8.5 emission scenario, the spatial distribution of flood hazard zones exhibits notable changes from 2025 to 2100, indicating increasing climate-induced vulnerability across the study area. In 2025, the very high flood hazard zone dominates with 37.03%, followed by the high hazard zone at 31.47%, showing that nearly 69% of the region remains under severe flood threat. By 2050, the distribution shifts as the very high hazard area decreases to 25.06%, while the moderate hazard zone increases sharply to 24.05%, reflecting the spread of risk into areas previously experiencing lower intensities. During the same period, the very low and low zones rise to 7.68% and 13.66%, respectively, suggesting localized reduction in extreme flood exposure. Moving into 2075, the high hazard zone again becomes dominant at 32.29%, while both moderate (23.53%) and very high (23.71%) hazard classes remain significantly high, indicating continuing and widespread susceptibility. By 2100, the high hazard category reaches its peak share of 32.80%, and the very high category rebounds to 28.09%, implying intensification of hydrological extremes toward the end of the century. The very low and low categories remain around 7.26% and 11.87%, suggesting limited improvement in flood resilience at lower-risk locations. Overall, the analysis highlights a persistent flood threat

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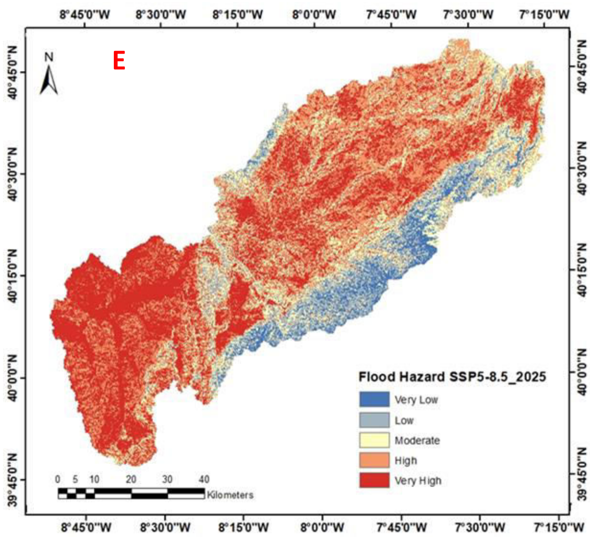
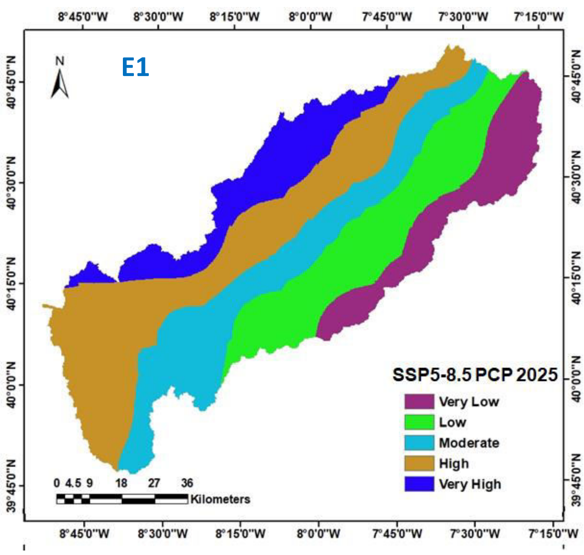
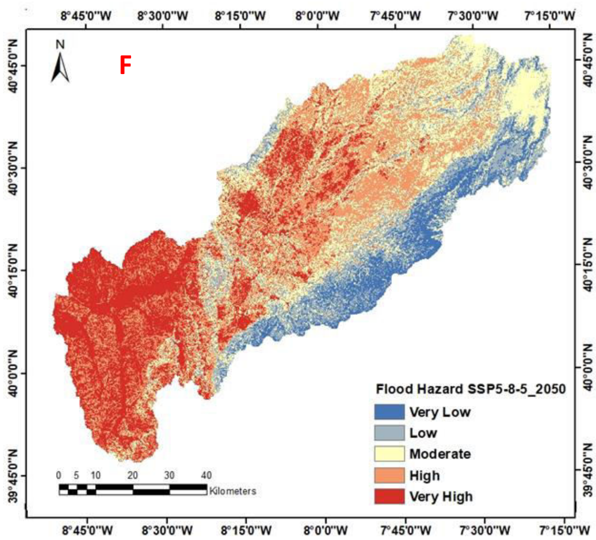
throughout the century, with a general shift from very high hazard areas toward high and moderate categories, yet still maintaining a large proportion under severe flood risk, driven by future climate change pressures on drainage, land use, and hydrological systems

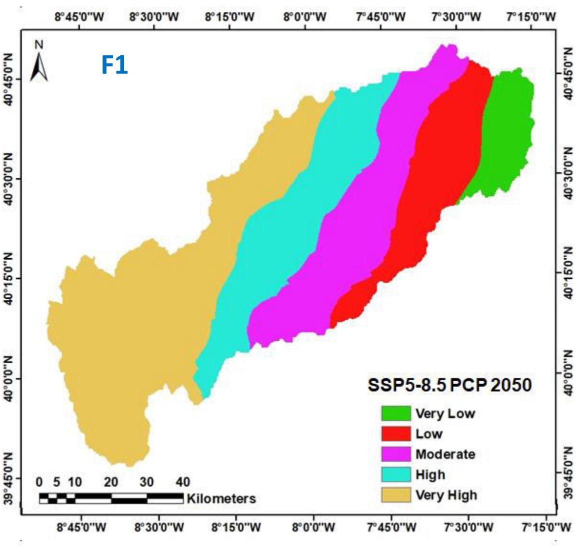
Table 4: Flood areas covered in the Mondego River Basin for different years of SSP 5-8.5

Flood Hazard Zone	Flood Hazard Area covered in Km^2 of emission scenario SSP5-8.5			
	Year-2025 (Fig.E)	Year-2050 (Fig.F)	Year-2075 (Fig.G)	Year-2100 (Fig. H)
Very Low	315	507	474	479
Low	671	901	877	783
Moderate	1093	1587	1552	1319
High	2075	1949	2130	2164
Very High	2443	1653	1564	1852









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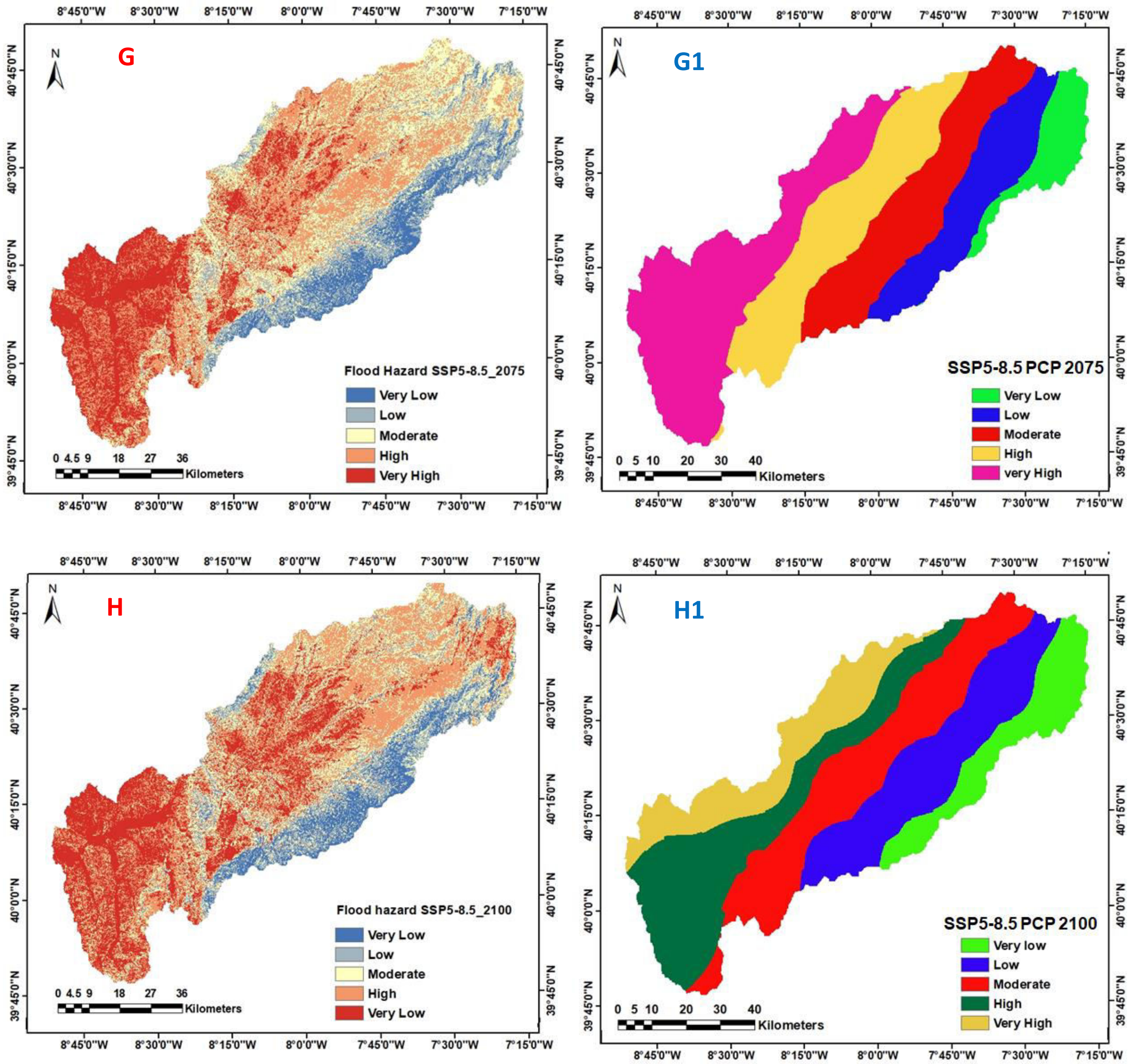

Figure 5: Flood Hazard maps for 2025 (E), 2050(F), 2075(G) and 2100(H) and corresponding Precipitation classes (E1), (F1), (G1), (H1) for emission scenario of SSP5- 8.5

IV. CONCLUSIONS

The primary objective of this research article is to identify and delineate the flood hazard zones within the Mondego River Basin, located in Portugal. This study utilizes precipitation data derived from the Global Climate Model (GCM) MIROC6 under two different Shared Socioeconomic Pathways (SSP) emission scenarios: SSP2-4.5 (medium stabilization scenario) and SSP5-8.5 (high fossil-fuel development scenario). The analysis is carried out for four key time frames of the 21st century: near future (2025), mid-century (2050), early end-century (2075), and end-century (2100). The graphical representation of flood hazard areas for different centuries with various SSP scenarios shown in figure 6.

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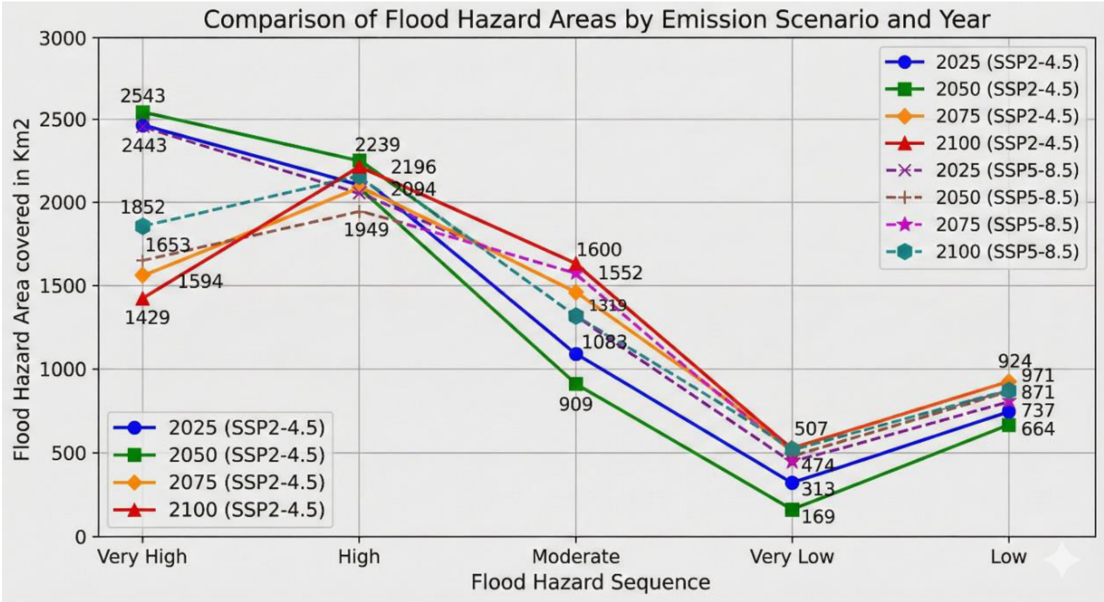

Figure 6: Comparison graph between different Emmission scenarios

To achieve this objective, the study adopts the Weighted Overlay Analysis (WOA) technique, which is a part of the Multi-Criteria Decision-Making (MCDM) framework. This approach is applied to compute and classify flood hazard zones into five categories**:** Very Low, Low, Moderate, High, and Very High hazard zones**.** For the implementation of the WOA method, six essential GIS grid layers are prepared, representing key factors influencing flood hazard: Slope Map, Flow Length Map, Precipitation Map, River Distance Map Land Use/Land Cover (LULC) Map, and Elevation Map. Table 5 gives the overall percentage change areas from SSP2-4.5 to SSP5-8.5 scenarios in 5 categories of flood hazard zones.

Table 5: Comparison Table of percentage changes in areas of different Emmission scenarios

Hazard Category	Avg Area (SSP2-4.5) km²	Avg Area (SSP5-8.5) km²	% Change
Very Low	380.50	443.75	+16.62%
Low	798.00	808.00	+1.25%
Moderate	1260.50	1387.75	+10.10%
High	2151.00	2079.50	−3.32%
Very High	2007.00	1878.00	−6.43%

Each of these layers is reclassified based on their respective ranges and assigned weightage percentages according to their relative influence on flood hazard: Slope (40%)**,** Flow Length (5%)**,** Precipitation (15%)**,** River Distance (5%)**,** Land Use/Land Cover (5%)**,** and Elevation (30%**)**. These weights ensure that the most significant factors, such as slope and elevation, have a greater impact on the final flood hazard mapping. The WOA was executed using ArcGIS 8.1 software, which integrates these weighted layers to generate a composite flood hazard map for each scenario and time frame. The results of this analysis are systematically discussed in the subsequent sections, comparing the spatial variations of flood hazard zones under different climate change scenarios and future timelines.

A comparison of flood hazard variations under the SSP2-4.5 and SSP5-8.5 scenarios reveals distinct differences in the severity and spatial evolution of future flood risks. Under SSP2-4.5, the proportion of very high flood hazard zones remains dominant in the near-future (≈37–39% in 2025–2050) but significantly decreases to ≈22% by 2100, suggesting partial redistribution of extreme flood exposure into moderate zones. In contrast, under the more intense SSP5-8.5 pathway, although a notable decline in very high hazard areas also occurs by 2050 **(**25.06%**),** a sharp rise is observed again toward the end of the century **(**28.09% in 2100**),** indicating renewed intensification of climatic extremes.

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Correspondingly, high hazard zones show a relatively stable pattern under SSP2-4.5 (≈31–34%), whereas under SSP5-8.5 they increase and remain higher in the long term (≈32–33%), reflecting exacerbated flow dynamics and runoff contributions. The overall Flood hazard areas percentage in different centuries for different hazard zonal areas as shown in figure 7.

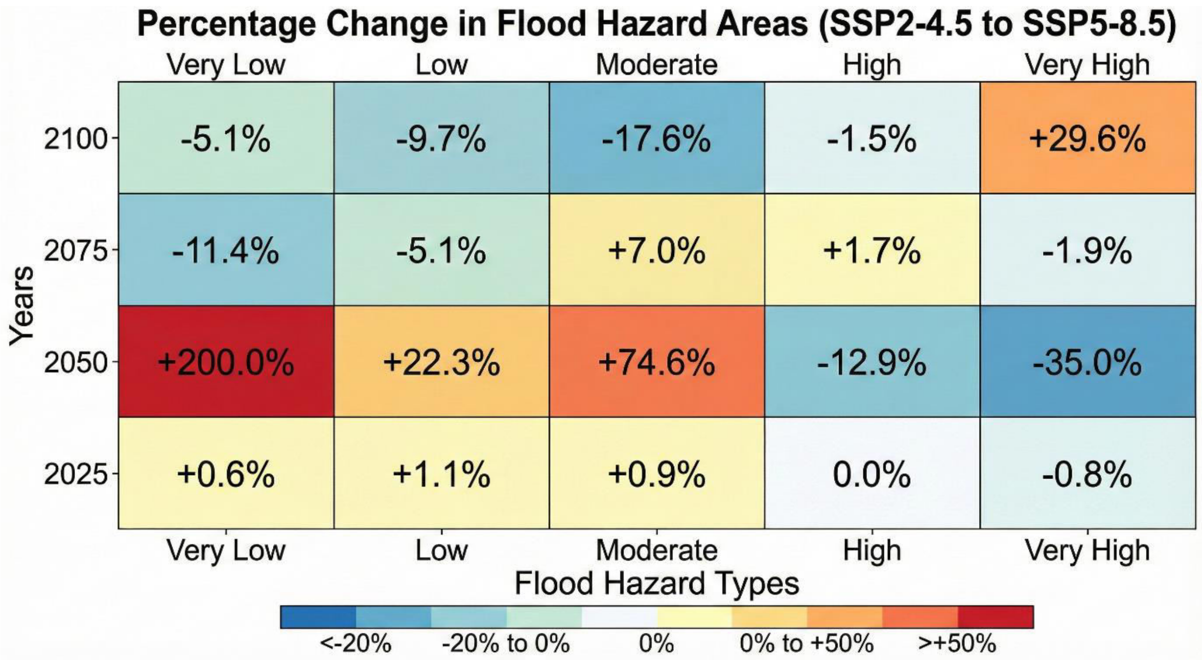

Figure 7: Percentage of difference between SSP2-4.5 and SSP5-8.6

The moderate hazard class expands consistently in both pathways, but the increase is more pronounced in SSP2-4.5 (reaching 24.3%**)** compared to 23.53% in SSP5-8.5 by 2075, demonstrating wider distribution of flood impacts when mitigation assumptions exist. Both scenarios show only modest improvements in low and very-low hazard zones, with shares generally remaining below 15%**,** indicating limited reduction in flood vulnerability despite different climate trajectories. Overall, the SSP2-4.5 projections indicate a diffusion of extreme flood risk into moderate zones**,** whereas SSP5-8.5 projections show persistent and intensifying high-severity flooding toward the end of the century, emphasizing that stronger climate forcing dramatically increases long-term hazard exposure and spatial severity. Ultimately, this study provides critical, forward-looking insights into the impacts of climate change on flood susceptibility in the Mondego River basin. It establishes Weighted Overlay Analysis as an essential tool for policymakers and planners, enabling proactive and science-based flood risk management and mitigation for the future. It can be concluded that the WOA-based approach is effective for delineating flood hazard zones using GIS layers without relying on complex modelling software. This work can be further strengthened by incorporating additional GCM datasets and exploring a wider range of emission scenarios

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