

## INTEGRATING GEOAI-BASED MARINE CONSERVATION WITH FIQH AND USUL AL-FIQH: A REVIEW

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**Abstract** - Marine ecosystems are increasingly threatened by climate change, unsustainable fishing, coastal development, and pollution, necessitating more sophisticated and value-driven approaches to conservation. Geospatial Artificial Intelligence (GeoAI), which integrates GIS, remote sensing, and artificial intelligence, has emerged as a powerful tool for marine environmental governance through its capabilities in spatial analysis, environmental monitoring, predictive modelling, and decision support. At the same time, the Islamic disciplines of Fiqh and Usul al-Fiqh offer a comprehensive ethical and legal framework grounded in principles such as *khilāfah* (stewardship), *mīzān* (balance), *maqāṣid al-sharī'ah* (higher objectives of Islamic law), *maṣlaḥah* (public interest), and *sadd al-dharī'ah* (blocking the means to harm). This paper conceptually explores the integration of GeoAI with Islamic jurisprudential principles to develop a holistic framework for marine conservation. It first outlines key GeoAI applications and then examines how Fiqh and Usul al-Fiqh can guide the ethical use of these technologies, particularly through *maqasid-oriented* governance and preventive approaches informed by *sadd al-dharī'ah*. The study concludes that GeoAI can serve as an effective instrument to operationalise Islamic environmental ethics by providing empirical evidence for ethically grounded policy decisions. The proposed integration strengthens both scientific robustness and moral legitimacy in marine governance, especially in Muslim-majority contexts, and highlights future directions for institutional frameworks, capacity-building, and interdisciplinary collaboration.

**Keywords:** GeoAI; Marine Conservation; Fiqh; Usul Al-Fiqh; Maqāṣid al-Sharī'ah; Islamic Environmental Ethics

### INTRODUCTION

Marine ecosystems worldwide are experiencing accelerated degradation driven by climate change, unsustainable fishing, coastal development, and pollution. These pressures threaten coral reefs, sea turtle nesting habitats, seagrass meadows, and fisheries that sustain millions of people. As environmental challenges grow more complex, modern conservation increasingly relies on Geospatial Artificial Intelligence (GeoAI), which is the integration of GIS, remote sensing, and artificial intelligence, to analyse spatial patterns, automate habitat classification, detect ecological anomalies, and predict future environmental risks<sup>1,2</sup>. GeoAI enables high-resolution monitoring and data-driven decision-making, making it a critical tool for effective marine conservation and long-term ecosystem resilience.

Within the Islamic intellectual tradition, Fiqh and Usul al-Fiqh provide a comprehensive ethical and legal framework that governs how humans should interact with the natural world. Core principles such as *khilāfah* (stewardship), *mīzān* (ecological balance), and the prohibition of *fasād* (corruption on land and sea) emphasise the importance of protecting the environment as a religious duty<sup>3</sup>. These values are reinforced through jurisprudential mechanisms including *maqāṣid al-sharī'ah* (higher objectives of Islamic law), *maṣlaḥah* (public interest), and *sadd al-dharī'ah* (blocking the means to harm), which collectively guide environmentally responsible decision-making<sup>4,5</sup>. Although the body of literature on Islamic environmental ethics is growing, the application of these principles to advanced technologies such as GeoAI remains limited and understudied.

Integrating GeoAI with Fiqh and Usul al-Fiqh, therefore presents a unique opportunity to develop a holistic, value-driven framework for marine conservation, one that is both scientifically robust and ethically grounded. GeoAI provides empirical evidence and predictive capability to identify vulnerable



habitats, evaluate development impacts, and support proactive marine governance. Islamic jurisprudence, in turn, offers moral direction that ensures conservation actions align with justice, sustainability, and the higher objectives of the *Shari'ah*. By synthesising these domains, this study seeks to fill an important gap in the literature and propose an interdisciplinary approach in which technological innovation reinforces Islamic stewardship principles, enabling more comprehensive and responsible marine environmental governance.

## GEOAI IN MARINE CONSERVATION

Marine ecosystems worldwide are experiencing accelerated degradation driven by climate change, unsustainable fishing, coastal development, and pollution. These pressures threaten coral reefs, sea turtle nesting habitats, seagrass meadows, and fisheries that sustain millions of people. As environmental challenges grow more complex, modern conservation increasingly relies on Geospatial Artificial Intelligence (GeoAI), which is the integration of GIS, remote sensing, and artificial intelligence, to analyse spatial patterns, automate habitat classification, detect ecological anomalies, and predict future environmental risks<sup>1,2</sup>. GeoAI enables high-resolution monitoring and data-driven decision-making, making it a critical tool for effective marine conservation and long-term ecosystem resilience.

### 1. Concept of GeoAI

Geospatial Artificial Intelligence (GeoAI) represents the amalgamation of geospatial technologies, such as GIS, satellite remote sensing, UAV photogrammetry, and in-situ environmental sensors, with artificial intelligence and machine learning algorithms<sup>6</sup>. Traditional geospatial analysis often relies heavily on manual classification, supervised interpretation, or deterministic modelling, which can limit the detection of complex spatial-temporal patterns. GeoAI addresses these limitations by utilising algorithms such as Random Forest (RF), Support Vector Machines (SVM), Convolutional Neural Networks (CNN), and deep learning architectures to automatically extract features, classify environmental phenomena, and model ecosystem behaviour with far greater precision and efficiency<sup>7</sup>. This shift allows researchers to process vast amounts of marine data that would otherwise be impractical to analyse manually. GeoAI fundamentally changes the role of the researcher from manual interpreter to intelligent system designer and decision analyst. By automating pattern recognition, GeoAI reduces subjectivity and increases reproducibility in spatial analysis. Its learning-based approach allows models to adapt to non-linear and dynamic environmental processes commonly found in marine systems. GeoAI is particularly valuable in marine environments where data complexity is driven by depth, water optics, and temporal variability. Unlike rule-based GIS models, GeoAI can learn hidden relationships without explicit physical assumptions. This capability enables the discovery of previously unrecognized spatial-temporal interactions. GeoAI also supports scalable analysis across regional to global marine domains. The integration of AI significantly improves processing speed compared to conventional GIS workflows. As marine datasets grow in volume and diversity, GeoAI becomes essential rather than optional.

Furthermore, GeoAI enhances the analytical power of marine conservation through its ability to integrate multi-source datasets<sup>8</sup>. Modern marine monitoring incorporates information from satellites such as Sentinel-2, Landsat-9, oceanographic models, autonomous sensors, UAVs, and field measurements. GeoAI can fuse these heterogeneous datasets to produce comprehensive, high-resolution insights into marine processes. This includes the detection of subtle spectral signatures of coral bleaching, the mapping of sedimentation pathways, or the prediction of harmful algal blooms<sup>8,9</sup>. Through its ability to handle large, diverse datasets and extract hidden patterns, GeoAI transforms raw geospatial information into meaningful environmental intelligence. In addition, data fusion within GeoAI enables spatial consistency across datasets with different resolutions and temporal frequencies. This integration reduces data gaps that often limit traditional marine assessments. GeoAI allows satellite-derived observations to be strengthened by in-situ and UAV-based measurements. Multi-sensor learning improves classification accuracy in optically complex coastal waters. GeoAI frameworks can dynamically weight data sources based on reliability and relevance. This adaptability is crucial in environments affected by turbidity, clouds, and seasonal variability. By integrating physical, biological, and chemical parameters, GeoAI supports holistic ecosystem assessment.

Most importantly, GeoAI supports predictive and prescriptive analytics, enabling conservationists and policymakers to anticipate future ecological scenarios rather than merely reacting to observed changes. For instance, predictive models can estimate future shoreline retreat, bleaching probability under different climate scenarios, or the likelihood of illegal fishing events based on vessel movement



patterns. For instance, predictive GeoAI models allow scenario-based planning under multiple climate and development pathways. These models help identify high-risk zones before irreversible degradation occurs. Prescriptive analytics further suggest optimal intervention strategies based on predicted outcomes. GeoAI enables early-warning systems for marine hazards such as coral bleaching and algal blooms. The spatially explicit nature of predictions improves resource prioritisation and enforcement efficiency. Meanwhile, GeoAI-driven risk maps support targeted conservation rather than uniform management approaches. Machine learning enhances forecasting accuracy by learning from historical spatial patterns. By integrating machine learning with spatial modelling, GeoAI becomes a powerful tool for proactive and adaptive marine management, which is essential in the context of accelerating environmental change.

## 2. GeoAI Applications in Marine and Coastal Systems

### Coral Reef Health Assessment

GeoAI has revolutionised the way coral reefs are mapped, monitored, and evaluated <sup>7,10,11</sup>. Through machine learning classification of high-resolution multispectral and hyperspectral imagery, researchers can distinguish between live coral, macroalgae, dead coral rubble, sand, and seagrass more accurately than through manual interpretation alone. Deep learning approaches, particularly CNNs, have demonstrated exceptional performance in recognising complex benthic patterns that were previously difficult to detect with classical GIS techniques <sup>12,13</sup>. These capabilities allow for up-to-date reef health maps that support both scientific research and conservation planning <sup>10</sup>. Beyond classification, GeoAI enables the development of predictive models that assess coral bleaching risk based on environmental parameters such as sea surface temperature (SST), degree heating weeks, light stress, turbidity, and historical bleaching events <sup>14</sup>. These models help identify climate refugia, which is the areas where reefs are more resilient to warming oceans, and inform targeted conservation interventions such as marine protected area (MPA) zoning or coral restoration site selection <sup>15</sup>. As climate-related disturbances become more frequent, such predictive tools are critical to mitigating coral reef decline.

### Sea Turtle and Marine Megafauna Conservation

GeoAI supports marine megafauna conservation by integrating satellite data, telemetry tracking, and coastal environmental variables into spatial-temporal analyses. Sea turtle nesting habitat suitability models, for example, incorporate factors such as beach slope, sediment type, vegetation cover, wave energy, and artificial light intensity <sup>16</sup>. Machine learning algorithms then generate detailed maps that highlight optimal nesting zones and areas vulnerable to disturbance from tourism or development. These outputs assist managers in establishing buffer zones, regulating coastal lighting, and assessing development proposals along sensitive coastlines. In addition, tracking data from GPS-tagged turtles, dolphins, and other megafauna can be analysed using GeoAI to identify migration routes, foraging hotspots, and behavioural responses to environmental change <sup>17,18</sup>. When combined with oceanographic variables like chlorophyll-a concentration, sea surface height, and current velocity, GeoAI models can predict habitat use patterns across seasons. This improves the design of seasonal fishing closures, vessel speed regulations, and protected areas, which can reduce the likelihood of bycatch, ship strikes, or habitat encroachment.

### Fisheries and Habitat Suitability Modelling

GeoAI offers significant advancements in fisheries science by enabling the prediction of fish species distribution and biomass based on environmental variables <sup>19</sup>. Machine learning models can analyse large datasets linking fish occurrence records with SST, salinity, dissolved oxygen, chlorophyll-a, bathymetry, currents, and substrate type <sup>20</sup>. These models identify suitable habitats for both pelagic and demersal species, helping fisheries managers understand how environmental conditions shape distribution patterns <sup>21</sup>. Such information is essential for assessing stock health, preventing overfishing, and designing sustainable harvest strategies. Furthermore, GeoAI facilitates the identification of essential fish habitats, including spawning grounds, nursery areas, and feeding hotspots. Temporal analysis allows researchers to predict how fish distribution may shift in response to climate variability, El Niño-Southern Oscillation (ENSO) cycles, or anthropogenic pressures. This predictive capability supports adaptive fisheries management, anticipating changes before they negatively affect fisheries productivity or ecosystem integrity.

### Coastal Erosion and Climate Impacts

GeoAI plays a crucial role in modelling coastal geomorphological processes by integrating historical shoreline data<sup>22</sup>, wave climate, sediment transport dynamics, sea-level rise projections, and land-use patterns<sup>23,24</sup>. Machine learning algorithms can detect patterns in shoreline movement that are not evident through traditional linear models. These predictive models allow the simulation of future shoreline positions, erosion hotspots, and coastal vulnerability scenarios. Such insights support the development of coastal setback lines, erosion mitigation strategies, and nature-based solutions such as mangrove restoration. Climate change intensifies the vulnerability of coastal communities, making GeoAI-based predictive tools even more essential<sup>25</sup>. By modelling interactions between sea-level rise, storm surge frequency, precipitation patterns, and land-use changes, GeoAI helps identify communities and infrastructures at greatest risk. This information guides disaster risk reduction planning, coastal development regulations, and long-term climate adaptation strategies.

### Marine Pollution Mapping

GeoAI enables automated detection of marine pollution events using multispectral, hyperspectral, or SAR (Synthetic Aperture Radar) imagery. Oil spills, sediment plumes, harmful algal blooms, and nutrient hotspots exhibit distinct spectral signatures that machine learning algorithms can efficiently extract<sup>26,27</sup>. GeoAI also improves pollution source tracing by analysing correlations between pollutant concentration, land-use patterns, industrial discharge locations, vessel movement, and atmospheric conditions. Predictive GeoAI models can forecast pollution dispersion patterns based on currents, wind, tides, and ocean turbulence<sup>28,29</sup>. These models are essential for emergency response, resource damage assessment, and ongoing water quality monitoring. By providing early warning signals and near-real-time tracking<sup>30</sup>, GeoAI supports regulatory enforcement and environmental protection across coastal and marine jurisdictions.

## 3. Importance of GeoAI for Marine Governance

GeoAI provides a transformative decision-support system that enhances marine spatial planning, environmental impact assessment (EIA), and monitoring, control, and surveillance (MCS)<sup>27</sup>. With its ability to detect environmental changes rapidly and predict future scenarios, GeoAI supports evidence-based policy development, allowing governments to allocate resources efficiently and respond to environmental threats proactively. This reduces uncertainty in management decisions and increases the effectiveness of conservation interventions. Moreover, GeoAI promotes transparency and accountability in marine governance<sup>30</sup>. High-resolution maps and predictive models provide accessible visual tools for communicating risks, conservation priorities, and policy justifications to stakeholders, including local communities, conservation organisations, and regulatory agencies. This strengthens participatory governance and increases public trust in environmental decision-making processes.

## FIQH AND USUL AL-FIQH: ETHICAL FOUNDATIONS FOR MARINE STEWARDSHIP

### 1. Ethical Basis

Islamic teachings place significant emphasis on the protection and sustainable use of natural resources to establish a moral and spiritual foundation for environmental stewardship<sup>3,31</sup>. This emphasis reflects Islam's holistic worldview in which environmental care is inseparable from faith and moral conduct. Nature is viewed as a sign of divine wisdom, deserving respect and responsible interaction. The concept of *khilāfah* (vicegerency) positions humans as custodians of the Earth who are entrusted with maintaining ecological balance (*mīzān*) and preventing corruption (*fasād*) on land and sea. *Khilāfah* assigns accountability to humans for how environmental resources are governed and utilised. This responsibility extends beyond immediate human benefit to long-term ecological wellbeing. Environmental exploitation without restraint contradicts the ethical mandate of vicegerency. The Qur'an explicitly warns against causing destruction to the natural world<sup>32</sup>, affirming that environmental degradation is not only a physical harm but also a moral violation<sup>33,34</sup>. This framing elevates environmental harm to an ethical and spiritual transgression. Pollution and ecosystem destruction are thus understood as breaches of divine guidance. Such warnings are particularly relevant in the modern era of industrial and technological expansion. In the context of marine ecosystems, which are highly vulnerable to pollution, overexploitation, and climate change, the principle of *khilāfah* compels Muslims to engage in responsible management and conservation practices. Marine stewardship therefore becomes an expression of faith in action. This ethical lens strengthens the moral urgency of protecting oceans and coastal environments.



Complementing this is the concept of *amānah* (trust), which emphasises that natural resources do not belong to humans unconditionally; rather, they are a trust from Allah that must be used without causing harm. *Amānah* highlights that humans do not permanently own natural resources and will always be accountable for how they are used. Humans are stewards, not absolute owners, of environmental assets. Seas, coasts, coral reefs, and marine biodiversity fall under this trust, and their mismanagement constitutes a breach of ethical responsibility. This ethical breach carries both worldly and spiritual consequences. Marine degradation is therefore not value-neutral within the Islamic moral framework. Unsustainable exploitation represents a failure to uphold divine trust. This perspective aligns closely with the principles of environmental sustainability, where resources must be utilised in a way that preserves ecological integrity. In modern marine governance, this implies that scientific tools such as GeoAI should be employed not only for efficiency but also to honour this trust by ensuring long-term ecosystem resilience. Technological advancement thus becomes ethically meaningful when guided by *amānah*. GeoAI serves as a tool to fulfil moral responsibility, not merely technical optimisation. Its application aligns scientific innovation with ethical accountability.

Islamic ethics also incorporate the principles of *ihsān* (excellence) and *rahmah* (mercy), which extend to all living beings. These principles elevate environmental care beyond obligation to moral excellence. *Ihsān* encourages humans to act with care, precision, and responsibility and *Rahmah* promotes compassion toward both visible and unseen forms of life. These principles encourage compassion toward marine life, such as sea turtles, fish stocks, coral organisms, and coastal species that are part of the web of creation. Marine organisms are recognised as communities with intrinsic value. Their existence is not solely justified by human utility. From this standpoint, actions leading to habitat destruction, water pollution, or species decline are contrary to the spirit of mercy and excellence. Environmental harm reflects a failure to embody ethical refinement in human conduct. Careless development and pollution undermine the ethical pursuit of *ihsān*. Thus, the ethical foundations of Islam provide a compelling mandate for the integration of advanced conservation technologies, such as GeoAI, to protect and sustain marine ecosystems. GeoAI enables compassionate conservation through informed and precise decision-making. Its predictive capacity helps prevent harm before it occurs, aligning with the ethic of mercy. Therefore, the integration of Islamic ethics with GeoAI supports a morally grounded, technologically advanced approach to marine sustainability.

## 2. Usul al-Fiqh Principles Relevant to GeoAI-Based Conservation

The framework of Usul al-Fiqh (principles of Islamic jurisprudence) provides structured mechanisms through which environmental governance can be interpreted and justified. It offers a systematic method for translating ethical values into practical rules and policies. This framework allows Islamic law to respond to new and complex environmental challenges. Central to this is the concept of *Maqāṣid al-sharī'ah* (higher objectives of Islamic law), which emphasises the preservation of life (*hifz al-nafs*), wealth (*hifz al-māl*), lineage (*hifz al-nasl*), and intellect (*hifz al-'aql*)<sup>35,36</sup>. These objectives reflect the goal of promoting human and environmental wellbeing, which provide ethical guidance that extends beyond ritual practice into governance and policy. In marine conservation, these objectives translate into safeguarding food security through sustainable fisheries, protecting livelihoods dependent on marine resources, ensuring the continuity of marine species for future generations, and promoting scientific knowledge and innovation. This includes the use of GeoAI as a tool for monitoring and protecting marine ecosystems<sup>37,38</sup>. Sustainable fisheries directly support the protection of life and wealth and marine biodiversity conservation ensures ecological continuity aligned with lineage preservation. The promotion of GeoAI-based research supports intellect through scientific advancement. Hence, GeoAI aligns with maqasid by providing evidence-based insights that support policies designed to secure long-term human and ecological wellbeing. In this way, technology becomes a means to fulfil higher ethical objectives.

*Maṣlahah* (public interest) further strengthens the link between Islamic jurisprudence and environmental conservation<sup>39</sup>. It allows flexibility in governance when direct textual rulings are absent. *Maṣlahah* prioritises collective welfare over individual or short-term interests. In situations where explicit scriptural rulings do not exist, such as regulating coastal development impacts or monitoring illegal fishing through AI. *Maṣlahah* allows decision-makers to adopt measures that protect community welfare and ecological stability. This principle is particularly relevant in rapidly evolving technological contexts. It enables the ethical adoption of new tools without violating Islamic values. GeoAI models, which provide high-resolution data on coastal vulnerabilities, biodiversity hotspots, and pollution pathways, directly contribute to public interest by guiding policies that reduce harm, enhance resilience, and prevent resource collapse. Accurate spatial data improves transparency and accountability in decision-



making. Policy interventions informed by GeoAI help avoid costly environmental damage. Thus, *maṣlahah* serves as a bridge between Islamic ethical intentions and modern scientific conservation tools. It ensures that technological innovation is directed toward societal benefit.

Another important principle is *sadd al-dharī'ah* (blocking the means to harm). It directs the prevention of activities likely to cause environmental damage even before harm occurs<sup>40</sup>. This principle promotes precaution rather than reaction. It is especially relevant for environmental risks that may be irreversible. This principle is particularly relevant to predictive GeoAI applications, such as modelling shoreline erosion, forecasting coral bleaching, or detecting artificial light pollution affecting sea turtle nesting. Early detection allows intervention before severe ecological loss occurs. GeoAI strengthens preventive governance through spatial forecasting. When GeoAI identifies potential ecological threats, policy interventions guided by *sadd al-dharī'ah* become not only justified but necessary. Preventive action aligns with the Islamic objective of harm avoidance. Likewise, *qiyās* (analogy) allows jurists to derive rulings for modern environmental issues like industrial marine pollution or AI-based surveillance, by analogising them to rulings on water contamination, public rights over natural resources, and the prohibition of harm. *Qiyās* ensures continuity between classical rulings and modern challenges. It allows Islamic law to remain relevant in technologically advanced contexts.

Finally, *'urf* (custom) acknowledges the relevance of local practices and community knowledge in shaping environmental policies, provided they do not conflict with Islamic principles<sup>3</sup>. This principle recognises that local communities are key stakeholders in environmental management. Customary practices often reflect long-term ecological adaptation. Coastal and fisher communities often possess deep ecological knowledge accumulated across generations, such as traditional no-take zones, seasonal closures, or migratory fish patterns. Such knowledge complements scientific observations. Ignoring local practices may weaken conservation outcomes. Integrating this knowledge with GeoAI datasets enables more accurate models and culturally grounded conservation strategies. GeoAI benefits from local validation and contextual understanding. This integration improves trust and policy acceptance among communities. Thus, *'urf* complements scientific innovation, ensuring that marine conservation remains both locally relevant and Shariah-compliant. Together, Islamic jurisprudence and GeoAI form a balanced framework for sustainable marine governance.

## LINKING GEOAI AND ISLAMIC JURISPRUDENCE IN MARINE GOVERNANCE

### 1. GeoAI as a Means to Operationalise *Maqāṣid al-Sharī'ah*

GeoAI provides a powerful scientific foundation for environmental governance, and when aligned with *Maqāṣid al-Sharī'ah*, it becomes a tool that directly contributes to achieving the higher objectives of Islamic law. For example, the objective of protection of life is supported by GeoAI's ability to predict coastal hazards, model storm surges, and assess water quality, thereby protecting communities from environmental risks. Similarly, protection of wealth is reflected in the sustainable management of fisheries, aquaculture, and coastal economies using GeoAI-based predictions of fish movement, coral health, and habitat suitability. These insights help prevent resource collapse, which aligns with safeguarding wealth and livelihoods.

The objective of protection of lineage calls for intergenerational sustainability, ensuring that future generations inherit healthy ecosystems and functioning marine resources. GeoAI supports this by forecasting ecological degradation, detecting illegal activities, and identifying conservation priority areas. Hence, this can guide long-term governance decisions. Meanwhile, protection of intellect encourages the pursuit of beneficial knowledge and innovation, including advanced scientific tools. The use of AI-driven marine research, environmental modelling, and digital monitoring systems aligns with this objective, as these technologies promote deeper understanding of Allah's creation and support informed decision-making. In this sense, GeoAI becomes an instrument that directly supports the realization of Shariah objectives.

Integrating GeoAI with the maqasid framework also ensures that marine governance decisions are not merely reactive but strategic, ethical, and future-oriented. Predictive analytics help policymakers anticipate ecological threats and design interventions that uphold justice and public welfare. Thus, GeoAI enhances the capacity of Islamic governance to address modern environmental challenges while sticking to the principles of the *Shari'ah*.



## 2. *Sadd al-dharī'ah* and Predictive Conservation

The principle of blocking the means to harm is especially relevant to GeoAI because of the technology's predictive capabilities. Traditional environmental governance often responds to damage only after it has occurred. In contrast, GeoAI can identify early-warning signals by analysing spatial-temporal patterns in coral bleaching, shoreline erosion, pollutant dispersion, and illegal fishing activities. By forecasting harm before it materialises, GeoAI empowers policymakers to restrict activities or implement safeguards in accordance with *sadd al-dharī'ah*. This preventive approach is consistent with the Islamic emphasis on avoiding even the pathways that lead to harm. For instance, GeoAI models that identify light pollution hotspots near turtle nesting beaches can guide the implementation of lighting restrictions or buffer zones. Predictive shoreline erosion models can justify the prohibition of new coastal structures in high-risk areas to prevent future damage to communities and ecosystems. Similarly, AI-enabled vessel tracking systems that detect suspicious fishing patterns allow authorities to intervene before destructive fishing practices occur. Each of these applications reflects the essence of *sadd al-dharī'ah*, which is mitigating risks at their source to protect both human society and the natural world.

Moreover, the integration of GeoAI with Islamic preventive principles strengthens the legitimacy of environmental regulations. When evidence-based predictions align with jurisprudential mandates to prevent harm, decision-makers can enact stronger and produce more justifiable conservation policies. This synergy creates a governance model in which modern technology reinforces Islamic moral responsibility, ensuring that environmental protection is both scientifically grounded and ethically upheld.

## CONCLUSION AND FUTURE RECOMMENDATIONS

The integration of Geospatial Artificial Intelligence (GeoAI) with the principles of Fiqh and Usul al-Fiqh offers a transformative and holistic approach to marine environmental governance. As demonstrated throughout this study, GeoAI provides unprecedented capabilities in spatial analysis, environmental monitoring, predictive modelling, and decision support. These technologies enable the identification of vulnerable habitats, the forecasting of ecological risks, and the evaluation of development impacts with a level of precision and scale not achievable through traditional methods. Such scientific advancements align seamlessly with the ethical imperatives found within Islamic jurisprudence, which emphasise stewardship (*khilāfah*), ecological balance (*mīzān*), the prevention of harm (*sadd al-dharī'ah*), and the pursuit of public welfare (*maṣlahah*).

By examining the intersections between GeoAI and Islamic legal principles, this study demonstrates that modern conservation technologies can serve as instruments for realising the higher objectives of the *Sharī'ah* (*Maqāṣid al-Sharī'ah*). GeoAI supports the protection of life by identifying environmental hazards, safeguards wealth by sustaining fisheries and marine resources, preserves lineage by protecting ecosystems for future generations, and promotes intellect by advancing scientific knowledge. Furthermore, the predictive and preventive strengths of GeoAI reinforce the jurisprudential principle of *sadd al-dharī'ah*, allowing harmful outcomes to be anticipated and mitigated before they occur. In doing so, GeoAI strengthens the effectiveness and ethical justification of marine conservation policies within an Islamic governance framework.

Looking ahead, several future recommendations emerge from this integrated perspective. First, there is a need for institutional frameworks that formally incorporate Islamic legal principles into marine spatial planning, environmental impact assessments (EIA), and national conservation policies. Such frameworks would benefit from explicit guidance on how GeoAI outputs, such as habitat suitability maps, pollution forecasts, and erosion models, can be evaluated through the lens of *maqasid*, *maṣlahah*, and *sadd al-dharī'ah*. Second, stronger capacity-building initiatives are needed to equip policymakers, religious scholars, conservation practitioners, and local communities with the technical and jurisprudential knowledge required to interpret and apply GeoAI tools effectively. Collaborative training programs that integrate environmental science, AI, and Islamic jurisprudence would help bridge gaps between technology and ethics.

In conclusion, the synthesis of GeoAI with Fiqh and Usul al-Fiqh provides a compelling framework for addressing marine environmental challenges. It presents a model in which technological innovation is guided by moral responsibility and where Islamic jurisprudence is enriched by empirical evidence. This integrated approach not only enhances the effectiveness of marine conservation but also reaffirms humanity's sacred duty to protect and sustain the natural world as a trust from Allah. Such a framework

holds significant promise for shaping future environmental governance in Muslim-majority regions and beyond, ensuring that marine stewardship remains both scientifically advanced and spiritually grounded.

## REFERENCES

1. G. Mai, Y. Xie, X. Jia, N. Lao, J. Rao, Q. Zhu, Z. Liu, Y. Y. Chiang & J. Jiao, "Towards The Next Generation of Geospatial Artificial Intelligence," *International Journal of Applied Earth Observation and Geoinformation* 136 (2025): 104368.
2. S. Wang, X. Huang, P. Liu, M. Zhang, F. Biljecki, T. Hu, X. Fu, L. Liu, X. Liu, R. Wang, Y. Huang, J. Yan, J. Jiang, M. Chukwu, S. Reza Naghedi, M. Hemmati, Y. Shao, N. Jia, Z. Xiao, ... S. Bao, "Mapping The Landscape And Roadmap Of Geospatial Artificial Intelligence (GeoAI) in Quantitative Human Geography: An Extensive Systematic Review," *International Journal of Applied Earth Observation and Geoinformation* 128 (2024): 103734.
3. B. Ulum, F. Ihsāni, & H. Mahnan, "Islamic Ethics in Sustainable Environmental Resource Management," *INCOME: Innovation of Economics and Management* 4, no. 3 (2025): 81-86.
4. Hayat, M. S. Malik, M. W. Ali, M. Husnain, M. Shariff, & A. Haleem, "The Role of Islamic Environmental Ethics in the Alleviation of Climate Challenges and the Preservation of Ecosystem," *Russian Law Journal* XI (2023): 395-404.
5. H. F. Iqbal, & S. Shukla, "Green Values: Environmental Sustainability and Moderation in Religious Teachings," *International Journal of Research in Management* 7, no. 2 (2025): 92-98.
6. F. Mushtaq, L. M. Alhems, M. Farooq, & S. P. Tiwari, "A Comprehensive Review of Geomatics Based Coastal Zone Management in The Realm of Arabian Gulf, Saudi Arabia," *Discover Applied Sciences* 7, no. 2 (2025).
7. H. Chen, J. Cheng, X. Ruan, J. Li, L. Ye, S. Chu, L. Cheng, & K. Zhang, "Satellite Remote Sensing and Bathymetry Co-Driven Deep Neural Network for Coral Reef Shallow Water Benthic Habitat Classification," *International Journal of Applied Earth Observation and Geoinformation* 132 (2024): 104054.
8. B. Yong, K. Ismail, A. Ali, R. C. Hasan, & M. A. H. Muhamad, "Marine Landscape Mapping for Ecologically Relevant Habitat Suitability Modelling," *Earth Science Informatics* 18, no. 2 (2025).
9. S. G. Klein, C. Roch, & C. M. Duarte, "Systematic Review of The Uncertainty of Coral Reef Futures Under Climate Change," *Nature Communications* 15, no. 1 (2025): 2224.
10. C. Burns, B. Bollard, & A. Narayanan, "Machine-Learning for Mapping and Monitoring Shallow Coral Reef Habitats," *Remote Sensing* 14, no. 11 (2022).
11. T. Nguyen, B. Lique, K. Mengersen, & D. Sous, "Mapping of Coral Reefs with Multispectral Satellites: A Review of Recent Papers," *Remote Sensing* 13, no. 21 (2021).
12. S. Franceschini, A. C. Meier, A. Suan, K. Stokes, S. Roy, & E. M. P. Madin, "A Deep Learning Model for Measuring Coral Reef Halos Globally from Multispectral Satellite Imagery," *Remote Sensing of Environment* 292 (2023).
13. J. Li, D. E. Knapp, N. S. Fabina, E. V. Kennedy, K. Larsen, M. B. Lyons, N. J. Murray, S. R. Phinn, C. M. Roelfsema, & G. P. Asner, "A Global Coral Reef Probability Map Generated Using Convolutional Neural Networks," *Coral Reefs* 39, no. 6 (2020): 1805-1815.
14. Candela, K. Edelson, M. M. Gierach, D. R. Thompson, G. Woodward, & D. Wettergreen, "Using Remote Sensing and in situ Measurements for Efficient Mapping and Optimal Sampling of Coral Reefs," *Frontiers in Marine Science* 8 (2021).
15. Rodriguez-Ramirez, M. González-Rivero, O. Beijbom, C. Bailhache, P. Bongaerts, K. T. Brown, D. E. P. Bryant, P. Dalton, S. Dove, A. Ganase, E. V. Kennedy, C. J. S. Kim, S. Lopez-Marcano, B. P. Neal, V. Z. Radice, J. Vercelloni, H. L. Beyer, & O. Hoegh-Guldberg, "A Contemporary Baseline Record of The World's Coral Reefs," *Scientific Data* 7, no. 1 (2020).
16. J. C. Christiaan, J. A. A. Antolínez, A. P. Luijendijk, P. Athanasiou, C. M. Duarte, & S. Aarninkhof, "Distribution of Global Sea Turtle Nesting Explained from Regional-Scale Coastal Characteristics," *Scientific Reports* 14, no. 1 (2024).
17. M. M. P. B. Fuentes, M. Beal, & A. R. Patricio, "The Elusive Sex: Satellite Tracking Contributions to Male Sea Turtle Spatial Ecology," *Endangered Species Research* 57 (2025).
18. Fujisaki, K. M. Hart, D. Bucklin, A. R. Iverson, C. Rubio, M. M. Lamont, R. de Jesus Gonzales Diaz Miron, P. M. Burchfield, J. Peña, & D. J. Shaver, "Predicting Multi-Species Foraging Hotspots for Marine Turtles in The Gulf of Mexico," *Endangered Species Research* 43 (2020): 253-266.
19. M. A. Karp, M. Cimino, J. K. Craig, D. P. Crear, C. Haak, E. L. Hazen, I. Kaplan, D. R. Kobayashi, H. Moustahfid, B. Muhling, M. L. Pinsky, L. A. Smith, J. T. Thorson, & P. A. Woodworth-Jefcoats, "Applications of Species Distribution Modeling and Future Needs to Support Marine Resource Management," *ICES Journal of Marine Science* 82, no. 3 (2025).
20. E. Abad, F. Izquierdo, J. Landa, F. Velasco, M. Hidalgo, & M. G. Pennino, "Identifying Spatiotemporal Variations in Four-Spot Megrim (*Lepidorhombus boscii*) Fishery Nurseries to Enhance Management and Stock Assessment," *Frontiers in Marine Science* 12 (2025).
21. R. Musimwa, W. Standaert, M. Stevens, S. J. Fernández Bejarano, C. Muñiz, E. Debusschere, S. Pint, & G. Everaert, "Climate-Induced Habitat Suitability Modelling for Pelagic Fish in European Seas," *Frontiers in Marine Science* 12 (2025).
22. N. Ridzuan, "Evaluating Coastal Erosion and Accretion Along Batu Ferringhi Beach with Digital Shoreline Analysis System," *BIO Web of Conferences* 176 (2025).
23. M. Lundine, & A. Trembanis, "Data-Driven Shoreline Modeling: Historical Remote Sensing and Prediction Methods," *SSRN* (2024).

- 
24. S. Vitousek, K. Vos, K. D. Splinter, K. Parker, A. O'Neill, A. C. Foxgrover, M. K. Hayden, J. A. Thomas, L. Erikson, & P. L. Barnard, "Scalable, Data-Assimilated Models Predict Large-Scale Shoreline Response to Waves and Sea-Level Rise," *Scientific Reports* 14, no. 1 (2024).
  25. Demetris, M. Christodoulos, E. Evagoras, S. Neophytos, E. Marinos, T. Christos, C. Antonis, H. Thomas, & H. Diofantos, "A Review of Open Remote Sensing Data with GIS, AI, and UAV Support for Shoreline Detection and Coastal Erosion Monitoring," *Applied Sciences* 9 (2025).
  26. K. Kikaki, I. Kakogeorgiou, I. Hoteit, & K. Karantzos, "Detecting Marine Pollutants and Sea Surface Features with Deep Learning in Sentinel-2 Imagery," *ISPRS Journal of Photogrammetry and Remote Sensing* 210 (2024): 39-54.
  27. N. Prakash, & O. Zielinski, "AI-Enhanced Real-Time Monitoring of Marine Pollution: Part 1-A State-Of-The-Art and Scoping Review," *Frontiers in Marine Science* 12 (2025).
  28. R. Al-Ruzouq, M. B. A. Gibril, A. Shanableh, A. Kais, O. Hamed, S. Al-Mansoori, & M. A. Khalil, "Sensors, Features, and Machine Learning for Oil Spill Detection and Monitoring: A Review," *Remote Sensing* 12, no. 20 (2020): 1-42.
  29. S. T. Yekeen, & A. L. Balogun, "Advances in Remote Sensing Technology, Machine Learning and Deep Learning for Marine Oil Spill Detection, Prediction and Vulnerability Assessment," *Remote Sensing* 12, no. 20 (2020): 1-31.
  30. M. Zakzouk, A. M. Abdulaziz, I. Abou El-Magd, A. S. Dahab, & E. M. Ali, "Automated Oil Spill Detection Using Deep Learning and SAR Satellite Data for The Northern Entrance of The Suez Canal, Prediction and Vulnerability Assessment," *Scientific Reports* 15, no. 1 (2025).
  31. Gayo, E. Djuniarti, M. H. M Z, D. D. L. O. Malim, E. L. P. Nugrahani, P. N. Utami, S. Aristeus, & E. N. A. M. Sihombing, "Marine Conservation in the Seafaring Tradition of Lhok Teunom Coastal, Aceh Jaya Regency, Aceh, Indonesia: An Analysis from the Perspective of Fiqh Al-Bi'ah," *Journal of Islamic Thought and Civilization* 15, no. 2 (2025): 306-326. Qur'an 7:56
  32. M. Maga Sule, M. Salihi, A. Musa, M. M. Sule, & S. A. Musa, "Islam and Environmental Stewardship... Islam and Environmental Stewardship: Da'wah as a Viable Alternative," *Ishraqi* 24, no. 1 (2025).
  33. Subagiya, "Environmental Fiqh and Protecting Nature: How Islamized View on Nature Implemented," *Indonesian Journal of Islamization Studies* 2, no. 2 (2025): 280-294.
  34. S. A. Ahmad Shukor, A. Aldizar, L. Alhazami, & S. Mareta, "Oceanic Economic Resilience Policy: An Islamic Perspective for Coastal Sustainability," *Jurnal Lemhannas RI* 12, no. 3 (2024): 403-416.
  35. M. K. Khuluq, & A. Asmuni, "Hifz Al-Bi'ah as Part of Maqashid Al-Shari'ah and Its Relevance in the Context of Global Climate Change," *Indonesian Journal of Interdisciplinary Islamic Studies* 7, no. 2 (2025).
  36. A. Abdur-Rauf, E. M. T. E. Ali, S. A. Yusuf-Saba, & R. K. Showole, "Conceptual and Practical Dimensions of Islamic Finance for Sustainable Blue Economy for Halal Sustainability," in M. A. Salisu, L. Raimi, N. B. Bamiro, & I. O. Elegbede (Eds.), *Green and Blue Economy Frameworks for Halal Industry Sustainability* (Springer Nature: Singapore, 2025).
  37. P. R. Citaningati, & T. Alfianto, "Blue Economics in Islamic Economics Perspective: Fiqh Bi'ah Approach," *Journal of Islamic Economic Laws* 7, no. 2 (2024): 128-160.
  38. M. Yusuf, "Strengthening Eco Fiqh: an Intergration of Texts and Maslaha on Environmental Impact Analysis," *Al-Daulah Jurnal Hukum Dan Perundangan Islam* (2020).
  39. W. Z. Wan Hassan, & N. Md Noor, "Application of Sadd al-Dhara'i' Theory in Curbing the Climate Change and Environmental Crisis in Malaysia in Parallel to the Demands of Maqasid Shariah," *International Journal of Academic Research in Business and Social Sciences* 15, no. 3 (2025).