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Department Hydraulique
Laboratoire de Recherché des Sciences de l'eau (LRS-EAU)



Doctoral Thesis

Field: Hydraulics

Specialty: Water Science and Environnement

Influence of the Spatio-Temporal Dynamics of Land Use and Land Cover on Flood Risk

Publicly defended before the members of the jury on (17/01/2026)

Prepared by HASNAOUI Yacine

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ENP 2026

Thèse préparée au Laboratoire de Recherche en Sciences de l'Eau (LRS-Eau), École Nationale Polytechnique (ENP), 10 avenue des Frères Oudek, Hassen Badi, BP 182, 16200 El Harrach, Alger, Algérie



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Thèse de doctorat

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Influence de la dynamique spatio-temporelle de l'occupation et de l'utilisation des sols sur le risque d'inondation

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الملخص:

تتناول هذه الدراسة التهديد المتزايد للفيضانات المفاجئة في الجزائر، لا سيما في حوض الحضنة، والذي تفاقم بفعل التغيرات المناخية والتوسع العمراني السريع، وتقتصر مقاربة مبتكرة ومكاملة لتحسين رسم خرائط الفيضانات وقابليتها بالاعتماد على الذكاء الاصطناعي الجغرافي (Geo-AI) الذي يدمج بين تقنيات التعلم الآلي والبيانات الجيومكانية ونظم المعلومات الجغرافية. ركز الجزء الأول على تحسين التنبؤ بالفيضانات المفاجئة من خلال دمج عوامل هيدرولوجية وطبوغرافية متعددة ضمن منهجية التجميع المتراكم (Stacking Ensemble) التي جمعت بين نموذج CatBoost والشبكات العصبية الالتفافية (CNNs)، وشبكات الذاكرة طويلة قصيرة المدى (LSTMs)، وشبكات الاعتقاد العميق (DBNs)، حيث حقق نموذج CatBoost-CNNs دقة تنبؤية بلغت 92%. أما الجزء الثاني فقد تناول تحليل الديناميكيات الزمانية-المكانية لتغيرات استخدامات الأراضي والغطاء الأرضي (LULC) خلال الفترة 2000-2020 مع إسقاط الاتجاهات المستقبلية حتى عام 2040، اعتمادًا على بيانات Landsat ونموذج CA-Markov الهجين. ولتعزيز النتائج، تم دمج محاكاة هيدروديناميكية مفصلة باستخدام نموذج HEC-RAS لدراسة المقاطع الحرجة من وادي القصاب بولاية المسيلة، مما أسهم في تحسين فهم سلوك الجريان وتقييم مخاطر الفيضانات بدقة، ويبرز ذلك فعالية النهج المقترح كأداة داعمة لاتخاذ القرار في إدارة مخاطر الفيضانات والتخطيط العمراني.

الكلمات المفتاحية: الفيضانات المفاجئة، الذكاء الاصطناعي الجغرافي، البيانات الجيومكانية، التعلم الآلي، نظم المعلومات الجغرافية.

Résumé

Cette étude aborde la menace croissante des crues subites en Algérie, en particulier dans le bassin de la Hodna, exacerbée par le changement climatique et l'urbanisation rapide. Elle propose une approche innovante et intégrée visant à améliorer la cartographie des inondations en s'appuyant sur la Géo-IA, intégrant des techniques d'apprentissage automatique (ML) et d'apprentissage profond (DL) avec les données géospatiales et les Systèmes d'Information Géographique (SIG). La première partie se concentre sur l'amélioration de la prédiction des crues subites, en intégrant divers facteurs hydrologiques et topographiques provenant de multiples sources de données. Une méthodologie d'ensemble en empilement (stacking ensemble) a été développée, combinant les modèles CatBoost avec des architectures de réseaux neuronaux convolutifs (CNNs), les réseaux de neurones à mémoire à long terme (LSTMs) et les réseaux de neurones à mémoire profonde (DBNs). Cette approche a démontré une performance prédictive exceptionnelle, notamment pour CatBoost-CNNs, atteignant 92 % de précision. La deuxième partie analyse les interactions complexes entre le risque d'inondation et les dynamiques spatio-temporelles des changements d'occupation et d'utilisation des sols (LULC) sur une période de 20 ans (2000-2020) et projette les tendances futures jusqu'en 2040.

Les données Landsat ainsi qu'un modèle hybride CA-Markov ont été utilisés pour la classification du LULC et les prévisions futures. En complément de ces approches prédictives basées sur l'IA, la thèse intègre des simulations hydrodynamiques détaillées utilisant HEC-RAS pour des tronçons critiques de l'Oued El Ksob à M'sila. Cette démarche offre une compréhension fine des écoulements et des hauteurs d'eau lors des crues, permettant d'identifier visuellement les zones inondables et de valider les prédictions des modèles d'IA à l'aide d'approches physiques.

Mots clés : Crues subites, GeoAI, apprentissage automatique, SIG, Modélisation hydrodynamique, LULC.

Abstract

This study addresses the escalating threat of flash floods in Algeria, particularly in the Hodna basin, which is exacerbated by climate change and rapid urbanization. It proposes an innovative and integrated Geo-AI approach to flood mapping, combining machine learning (ML) techniques with geospatial data and Geographic Information Systems (GIS). The first part focuses on enhancing flash flood prediction, integrating diverse hydrological and topographical factors from multiple data sources. A stacking ensemble methodology was developed, combining CatBoost models with Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTMs), and Deep Belief Networks (DBNs). This approach demonstrated exceptional predictive performance, particularly CatBoost-CNN, which achieved an accuracy 92% accuracy. The second part analyzes the complex interactions between flood risk and spatio-temporal dynamics of land use and land cover (LULC) changes over a 20-year period (2000-2020) and projects future trends until 2040. Landsat data and a hybrid CA-Markov model were used for LULC classification and future predictions. Complementing these AI-driven predictive approaches, the thesis integrates detailed hydrodynamic simulations using HEC-RAS for critical sections of the Oued El Ksob in M'sila.

Keywords: Flash floods, GeoAI, Machine Learning, Hydrodynamic Modeling, GIS.

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