الجمهورية الجزائريـــة الديمقراطيـــة الشعبيـــة
Democratic and Popular Republic of Algeria
وزارة التعليـم العالـــي والبحـث العلمـي
Ministry of Higher Education and Scientific Research
المدرسة الوطنية العليا للفلاحة الحراش – الجزائر
National Higher School of Agronomy – El Harrach – Algiers

Department : Rural Engineering
Speciality : Numeric agriculture

قسم : الهندسة الريفية
تخصص : زراعة دقيقة

Final Year Project

In order to obtain the Master's Degree

Theme

Wheat yield estimation based on remote sensing and GIS

Presented by: Bourada Loubna

Defended on: 18/12/2024

In front of the examination committee:

President:	Mr. DELLI Reda	(MCB – ENSA)
Supervisor:	Dr. LARIBI Abdelkader	(MCA – ENSA)
Co-supervisor:	Dr. TEFFAHI Hanane	(DOCTOR – ASAL)
Examinator:	Ms. KATMIR Houria	(MCB– ENSA)
	Ms. LOUNIS Amal	(MCB– ENSA)

Promotion : **2019 – 2024**

Table of contents

DEDICATION.....II
ACKNOWLEDGEMENT.....II
Abstract.....III
Résumé.....IV
خلاصة البحث.....V
List of Abbreviations and Acronyms.....VI
List of figures.....IX
List of tables.....XI
General introduction **1**
Chapter I.....6
Literature Review.....6
I.Literature Review of Cereal Crop Monitoring in Precision Agriculture (PA) **6**
I.1. Precision agriculture concept.....6
I.1.1. Precision agriculture definition.....6
I.1.2. Precision agriculture: the historical development of its meaning.....7
I.1.3. Why precision agriculture?.....10
I.1.4. Advantages and disadvantages of precision agriculture.....10
I.1.4.1. The benefits of precision agriculture (advantages).....10
I.1.4.1.1. The global benefits of precision agriculture.....10
I.1.4.1.1. Benefits of PA and its state in Algeria.....11
I.1.4.2. Challenges and barriers to adoption (disadvantages).....12
I.1.4.2.1. Global challenges.....12
I.1.4.1.2. Challenges to adopt precision agriculture in Algeria.....13
I.2. Generalities on cereal crop **13**
I.2.1. Origins and natural history of wheat.....16
I.2.2. Presentation of the wheat crop.....17
I.2.2.1. Scientific classification and nomenclature.....17
I.2.2.2. Wheat characteristics: plant features and properties.....18
I.2.2.2.1. The wheat grain.....19
I.2.2.2.2. The wheat plant.....20
I.2.2.3. Wheat growth stages: vegetative cycle.....21
I.2.2.3.1. Why do we grow wheat?.....21
I.2.2.3.2. How Does Wheat Grow?.....21

I.2.2.4. Wheat requirements 24
I.2.2.4.1. Climatic requirements 24
I.2.2.4.2. Rainfall requirements 25
I.2.2.4.3. Soil requirements 25
I.2.3. Wheat production and trade in Algeria 26
II. Fundamentals and Related Works of Remote Sensing, Geographic Information System (GIS) and Artificial Intelligence (AI) in the Agricultural Field 28
II.1. Geographic information system in agriculture 28
II.2.1. Geoinformatics in agriculture 30
II.2.1.1. Introduction to geoinformatics 30
II.2.1.1. The historical background, a remarkable history of Geographic Information System (GIS) and geoinformatics 31
II.2.1.1.1. Where did it all begin? 32
II.2.1.1.2. Between GIS and geoinformatics: 35
II.2.1.2. Geoinformatics in precision agriculture: 36
II.2.2. GIS in agriculture 36
II.2.2.1. Definition of the Geographic Information System or GIS 36
II.2.2.2. GIS functions 37
II.2.2.2.1. Data capture 37
II.2.2.2.2. Data management 37
II.2.2.2.3. Spatial analysis 37
II.2.2.2.4. Results presentation 38
II.2.2.2.5. Agricultural GIS Data: Where It Comes from And How It's Processed? 39
II.2. Remote Sensing (RS) 41
II.2.1. Definition of RS 42
II.2.2. Historical overview 42
II.2.3. Remote Sensing 44
II.2.3.1. components of Remote Sensing 44
II.2.3.2. Main remote sensing modes of observation 45
II.2.3.2.1. Passive observation mode 45
II.2.3.2.2. Active observation mode 46
II.2.3.3. Electromagnetic radiation and the electromagnetic spectrum 47
II.2.3.4. Remote Sensing images 48
1.Resolution's concept 51
2.Types of remote sensing imagery 51
II.2.3.5. Operations on Remote Sensing images 55

II.2.3.5.1. Image acquisition 56
II.2.3.5.2. Image Pre-processing 56
II.2.3.5.1.1. Geometric Corrections 56
II.2.3.5.1.1. Radiometric and atmospheric corrections 57
II.2.3.5.4. Remote Sensing image processing 57
1. Image Enhancement 58
2. Image transformation by spectral indices 58
3. Image segmentation 59
II.2.3.6. Applications of RS in agriculture 61
II.3. Ai for agriculture applications 62
II.3.1. Historical context of crop yield estimation techniques 63
II.3.2. Advances in remote sensing and GIS technologies 63
II.3.3. Application of artificial intelligence in agriculture 64
II.3.3.1. Definitions of AI 65
II.3.3.2. AI in agriculture 65
II.3.3.3. The process of AI adoption in agriculture 66
II.3.4. Machine learning in agriculture 67
II.3.3.4.1. Overview of machine learning applications in predicting yields 67
II.3.3.4.2. Machine Learning models applied in agriculture for yield estimation 69
Chapter II 71
Material and Methods: Problematic and resolving methods 71
II.1. Objectives 71
II.2. Problematic and motivation 71
II.3. Study area description 73
III.4. Machine learning techniques for crop yield estimation 75
III.4.1. Applications of AI in agriculture 75
III.4.2. definition of machine learning 77
III.4.3. Classification methods 77
III.4.3.1. What is a classification algorithm? 77
III.4.3.2. ML techniques 78
III.4.3.2.1. Supervised learning: 78
III.4.3.2.2. Unsupervised learning 78
III.4.3.3. Classification 79
III.4.3.4. Regression 81
III.5. Methodology and framework description 82

III.5.1. Random Forest Classification 83
III.5.1.1. How RF Classification works 83
III.4.1.2. Flowchart of the Random Forest Classification Algorithm 84
III.5.1.3. Application in land use classification 85
III.5.2. RF regression 86
III.5.2.1. Flowchart of the RF regression 86
III.5.4. XGBoost classification 87
III.5.4.1. XGBoost definition 87
III.4.4.2. XGBoost algorithm for classification 88
CHAPTER III 91
Results and discussions 91
III.1. Experiments 91
III.1.1. Dataset description and preparation 91
III.1.1.1. Ground truth data 91
III.1.1.2. Imagery data 94
III.1.1.2.1. Sentinel-2 images 94
III.3.2.1. Landsat 8 Images: 96
III.1.2. Experimentation 97
III.1.3. Results and analysis 105
CHAPTER IV 107
BUSINESS PLAN 107
IV.1. The Origin of the Idea 107
IV.2. Motivations and Strengths 107
IV.3. Description of the Offer 108
IV.4. Sales Tools 108
IV.5. Project Launch Calendar 109
IV.6. SWOT Analysis 112
General Conclusion 114
References 116
Annexes 127

Abstract

This thesis investigates the application of remote sensing and Geographic Information Systems (GIS) for estimating and forecasting wheat yields in the Tipaza region of Algeria. As agriculture faces increasing challenges from climate change and resource limitations, accurate yield estimation becomes critical for enhancing productivity and ensuring food security. Utilizing high-resolution satellite imagery from Sentinel-2 and Landsat 8, this study develops a comprehensive methodology that includes land use mapping, classification, and yield forecasting. The research begins with the acquisition of satellite images and ground truth data, which are processed using Google Earth Engine and QGIS to create detailed land use maps. Classification algorithms, specifically Random Forest and XGBoost are employed to categorize agricultural practices effectively. The classification results are validated against real yield data and agricultural statistics from the Algerian Directorate of Agricultural Services, ensuring the reliability of the findings. Following validation, Random Forest regression and XGBoost regression techniques are applied to predict wheat yields based on the classified land use data. Additionally, the study compares yield dynamics across other crops, including soft wheat, soybeans, and oats, providing a broader perspective on agricultural productivity in the region. The findings demonstrate that remote sensing technologies can significantly enhance yield estimation accuracy and contribute to sustainable agricultural practices. This research not only advances our understanding of wheat production in Tipaza but also proposes a predictive framework that can be adapted for wider application throughout Algeria. By integrating advanced technologies into agricultural monitoring, this thesis aims to support informed decision-making for farmers and policymakers, ultimately contributing to improved food security and resource management in the region.

Key words: geographic information system, remote sensing, sustainability, yield estimation, Wheat.

Résumé

Cette thèse examine l'application des technologies de télédétection et des systèmes d'information géographique (SIG) pour estimer et prévoir les rendements de blé dans la région de Tipaza en Algérie. Alors que l'agriculture fait face à des défis croissants dus au changement climatique et aux limitations des ressources, une estimation précise des rendements devient essentielle pour améliorer la productivité et garantir la sécurité alimentaire. En utilisant des images satellites à haute résolution provenant de Sentinel-2 et de Landsat 8, cette étude développe une méthodologie complète qui comprend la cartographie de l'utilisation des terres, la classification et la prévision des rendements. La recherche commence par l'acquisition d'images satellites et de données de terrain, qui sont traitées à l'aide de Google Earth Engine et de QGIS pour créer des cartes d'utilisation des terres détaillées. Des algorithmes de classification, tels que Random Forest et XGBoost sont employés pour catégoriser efficacement les pratiques agricoles. Les résultats de la classification sont validés par rapport aux données réelles de rendement et aux statistiques agricoles fournies par la Direction des services agricoles algérienne, garantissant ainsi la fiabilité des conclusions. Après validation, les techniques de régression Random Forest et XGBoost sont appliquées pour prédire les rendements du blé en fonction des données d'utilisation des terres classifiées. De plus, l'étude compare les dynamiques de rendement d'autres cultures, notamment le blé tendre, l'orge et l'avoine, offrant ainsi une perspective plus large sur la productivité agricole dans la région. Les résultats démontrent que les technologies de télédétection peuvent considérablement améliorer l'exactitude des estimations de rendement et contribuer à des pratiques agricoles durables. Cette recherche non seulement fait progresser notre compréhension de la production de blé à Tipaza, mais propose également un cadre prédictif qui peut être adapté à une application plus large à travers l'Algérie. En intégrant des technologies avancées dans le suivi agricole, cette thèse vise à soutenir une prise de décision éclairée pour les agriculteurs et les décideurs politiques, contribuant ainsi à améliorer la sécurité alimentaire et la gestion des ressources dans la région.

Mots clés : Blé, durabilité, Estimation du Rendement, Télédétection, Système d'Information Géographique (SIG)

خلاصة البحث

تتناول هذه الأطروحة تطبيق تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية لتقدير وتوقع إنتاج القمح في منطقة تيبازة الجزائرية. مع مواجهة الزراعة تحديات متزايدة نتيجة التغير المناخي وقيود الموارد، تصبح تقديرات الانتاج الدقيقة أمرًا ضروريا لتعزيز الإنتاجية وضمان الأمن الغذائي من خلال استخدام صور الأقمار الصناعية عالية الدقة من Sentinel-2 Landsat-8، تطور هذه الدراسة منهجية شاملة تشمل رسم خرائط استخدام الأراضي، والتصنيف، وتوقع الإنتاج. تبدأ الدراسة بجمع صور الأقمار الصناعية وبيانات الأرض، والتي تتم معالجتها باستخدام GOOGLE EARTH engine و QGIS لإنشاء خرائط تفصيلية لاستخدام الأراضي يتم استخدام خوارزميات التصنيف مثل Random Forest وXGBoost ، لتصنيف الممارسات الزراعية بشكل فعال. يتم التحقق من نتائج التصنيف من خلال مقارنة البيانات الحقيقية للإنتاج والإحصاءات الزراعية المقدمة من المديرية العامة للخدمات الزراعية الجزائرية، مما يضمن موثوقية النتائج. بعد التحقق، يتم تطبيق تقنيات الانحدارXGBoost و Random Forest لتوقع إنتاج القمح بناءً على بيانات استخدام الأراضي المصنفة. بالإضافة إلى ذلك، تقارن الدراسة طرق الإنتاج لزراعات أخرى، بما في ذلك القمح اللين والشعير. مما يوفر منظورًا أوسع لإنتاجية الزراعة في المنطقة. تظهر النتائج أن تقنيات الاستشعار عن بعد يمكن أن تعزز بشكل كبير دقة تقديرات الإنتاج وتساهم في ممارسات زراعية مستدامة. لا تساهم هذه الدراسة فقط في تعزيز فهمنا لإنتاج القمح في تيبازة، بل تقترح أيضًا إطارًا تنبؤيًا يمكن تكييفه للاستخدام الأوسع في جميع أنحاء الجزائر. من خلال دمج التقنيات المتقدمة في مراقبة الزراعة، تهدف هذه الأطروحة إلى دعم اتخاذ قرارات مستنيرة للمزارعين وصانعي السياسات، مما يساهم في تحسين الأمن الغذائي وإدارة الموارد في المنطقة

مفاتيح البحث

الاستشعار عن بعد، القمح، تقدير الإنتاج، نظام المعلومات الجغرافية