

IRRIGATION-INDUCED GROUNDWATER DEGRADATION IN A SEMI-ARID BASIN: HYDROGEOCHEMICAL AND SPATIAL EVIDENCE FROM CENTRAL TUNISIA

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ABSTRACT

Groundwater resources in semi-arid regions are increasingly threatened by irrigation-driven salinization and nitrate contamination. This study investigates the impact of irrigation on groundwater quality and recharge processes in the Regueb Basin (Central Tunisia) using an integrated approach combining hydrochemical analysis, irrigation water quality indices (SAR, %Na, IWQI), and GIS-based spatial modeling. Thirty groundwater samples were analyzed for major ions and in-situ physicochemical parameters. Results indicate highly mineralized groundwater with electrical conductivity ranging from 1,485 to 8,714 $\mu\text{S}/\text{cm}$ and nitrate concentrations reaching up to 130 mg/L, frequently exceeding WHO drinking water standards. Hydrochemical facies are dominated by Ca–Cl, Na–Cl, and Ca–Mg–SO₄ types, reflecting the combined effects of water–rock interaction, evaporation, and irrigation return flow. Irrigation water quality assessment reveals that more than 40% of samples fall into doubtful to unsuitable classes for irrigation due to elevated salinity and sodicity (high SAR and %Na values). GIS-based spatial analysis identifies clear degradation hotspots in intensively irrigated zones, where nitrate enrichment and salinization are most pronounced. The novelty of this work lies in the integrated coupling of hydrochemical indicators with GIS-based spatial modeling to simultaneously evaluate irrigation-driven recharge and groundwater quality deterioration. The findings highlight the dual role of irrigation in enhancing aquifer recharge while accelerating salinization and nitrate pollution, emphasizing the urgent need for sustainable irrigation management in semi-arid aquifers.

Keywords: Groundwater quality, Salinization, Semi-arid aquifers, Hydrogeochemistry, Irrigation Water Quality Index (IWQI), Sodium Adsorption Ratio (SAR), GIS spatial analysis, Tunisia.

ENVIRONMENTAL ASSESSMENT OF GROUNDWATER STRESS IN ALBANIA UNDER ANTHROPOGENIC AND CLIMATE PRESSURES USING THE ISARUN INDICATOR

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ABSTRACT

This paper presents an integrated assessment of groundwater dynamics across Albania's principal river basins Drini–Buna, Mati, Ishëm–Erzen, Shkumbin, Seman, and Vjosa based on long-term monitoring data covering two representative periods (2005–2009 and 2020–2024). The analysis quantifies multiannual changes in groundwater systems by combining hydrodynamic indicators with a composite index approach. Due to limitations in continuous long-term datasets, a comparative two-period methodology was adopted as a consistent basis for basin-scale analysis. The core assessment is based on the ISARUN indicator (Integrated Stress Assessment of Groundwater Resources). This composite index integrates normalized groundwater level trends, variability, recharge conditions, and anthropogenic pressure (expressed as the abstraction-to-recharge ratio) to provide a synthetic measure of groundwater stress. The results reveal pronounced spatial heterogeneity among basins. The Ishëm–Erzen and Shkumbin basins exhibit the highest stress levels (ISARUN $\approx$ 0.7–0.8), reflecting intensive groundwater abstraction combined with reduced recharge. In contrast, the Vjosa, Mati, and Seman basins show lower stress levels (ISARUN $\approx$ 0.4–0.5), indicating relatively higher system resilience, although a consistent declining trend in groundwater levels is observed across all basins. These findings demonstrate that groundwater dynamics in Albania are driven by the combined effects of climatic variability and increasing anthropogenic pressures, where the later plays a dominant role in highly urbanized and coastal basins. The consistency between ISARUN classification and observed groundwater trends supports the robustness of the indicator as a first order assessment tool under data limited conditions. The ISARUN classification was further validated against observed groundwater depletion trends and statistical analyses (Mann–Kendall), showing consistent basin ranking and confirming its reliability. Overall, the study identifies a systemic pattern of groundwater depletion at the national scale and highlights the need for strengthened monitoring, improved regulation of abstraction, and integrated basin-scale management. The ISARUN indicator used for the first time in Albania, provides a practical and adaptable approach for groundwater assessment in similar hydrogeological contexts.

Key-words: transboundary aquifer; groundwater quantity; groundwater, aquifer dynamics, hydroclimatic variability, monitoring network, resource depletion.

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AIR QUALITY MONITORING IN THE CITY OF SKOPJE BY PM_{2.5} CONCENTRATIONS, FOR THE PERIOD 2017-2021

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ABSTRACT

Air pollution is an environmental and social problem because it causes a multitude of harmful effects on human health, ecosystems, the built environment and the climate. Also, air pollution is a complex problem that presents numerous challenges in terms of management and mitigation. There are continuous trends from the authorities of the respective countries to mitigate air pollutants, however, the concentrations that are being recorded at air monitoring stations in different countries are presenting a great challenge for the entire globe. Because air pollution in recent decades has become more and more extensive in scope, stronger in effect and faster in time.

The concentration of PM_{2.5} in the air, are presenting serious problems for all countries of the world, and especially for countries with industrial development. Such a problem is also in the city of Skopje in the Republic of North Macedonia. The city of Skopje in the last decade has been constantly attacked by air pollution and according to the results of air pollution measurements, it has turned out to be the most polluted city in the world for several years. During the research we have done over the years; 2017-2021, in this city, multiple exceedances of PM_{2.5} were recorded. For this period of time, in the city of Skopje, at the central station, exceedances over the permitted rates were registered for a full 34 months. Also, other air pollutant parameters are presenting a problem for the citizens of Skopje, such as: PM₁₀, SO₂, NO₂, CO and O₃, registering exceedances over the permitted threshold, some of them in these years. The analyzes and processing of the results have been made in accordance with the laws of the Republic of North Macedonia, and in full compliance with; The Official Gazette of the Republic of North Macedonia, no. 4 of 9.1.2013, and with Directive 2008/50/EC, always for µg/m³.

Key words: Air, pollution, measurement, quality, concentrations, PM_{2.5}, Skopje.

VOLUME COMPUTED TOMOGRAPHY DOSE INDEX EVALUATION FOR CT SCANNERS OPERATING IN VARIOUS RADIOLOGY DEPARTMENTS ACROSS ALBANIA

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ABSTRACT

Computed Tomography (CT) is widely recognized as a relatively high-dose imaging modality. Therefore, dose optimization and the implementation of appropriate dose constraints are of particular importance. In Albania, the measurement of Volume Computed Tomography Dose Index (CTDI_{vol}) is a mandatory component of quality control (QC) testing for CT scanners, ensuring that CT systems operate within safe radiation dose limits while maintaining optimal image quality for accurate diagnoses. Evaluation of CTDI_{vol} is performed using a pencil ionization chamber in combination with standard PMMA phantoms: a 16cm diameter head phantom and a 32cm diameter body phantom. The aim of this study was to assess CTDI_{vol} values across different types of CT scanners operating in various radiology departments throughout Albania. All data were collected during the initial performance of QC testing procedures. Analysis of the results demonstrated that CTDI_{vol} measurements for the body phantom ranged from 12.5 mGy to 23.4 mGy, while measurements for the head phantom ranged from 35 mGy to 61.3 mGy. The relative differences between experimentally measured CTDI_{vol} values and the corresponding console-displayed values ranged from 0.7% to 17.0% for the body phantom and from 0.3% to 7.6% for the head phantom. This survey provides a valuable baseline assessment of CT scanner's performance across the country. Establishing such reference data enables standardized comparison over time, supports the tracking of equipment performance, and contributes to the optimization of imaging protocols.

Key words: quality control, CT scanner, CTDI volume, PMMA phantom, pencil ionization chamber.

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BACTERIAL CONTAMINATION ASSESSMENT OF FROZEN AND RAW MINCED MEAT IN TIARET, WESTERN ALGERIA: A SEMI-ARID REGION STUDY

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ABSTRACT

Food poisoning poses a real danger to populations in poor and developing countries, especially since these countries are located in hot and arid climates. Our study focuses on the risks that contaminated meat products can pose to consumer health. To this end, we assessed the contamination of fresh and frozen ground beef sold on the market. Randomly collected samples from different locations across the town revealed that aerobic mesophilic counts were 3.58×10^2 CFU/g in frozen minced meat and 4.05×10^2 CFU/g in raw minced meat. Coliforms were the predominant microorganisms, with counts of 3.87×10^2 CFU/g in frozen samples and 4.43×10^2 CFU/g in raw samples. *Staphylococcus aureus* was detected at levels of 3.80×10^2 CFU/g in frozen minced meat and 4.09×10^2 CFU/g in raw minced meat, while *Escherichia coli* counts were 3.27×10^2 CFU/g and 3.96×10^2 CFU/g in frozen and raw minced meat, respectively. Overall, raw minced meat exhibited higher microbial loads for all organisms analyzed. These results can only indicate the real danger to which this population is exposed.

Key words: Bacterial spoilage, frozen, raw, minced beef, intoxication.

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PESTICIDE RESIDUES IN ALBANIAN TOMATOES AND IMPLICATIONS FOR CONSUMER HEALTH

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ABSTRACT

Monitoring the residues of pesticides in fresh food is essential for evaluating dietary exposure and ensuring alignment with international food safety standards. In Albania, however, data on pesticide residues in vegetables and their associated consumer health risks remain scarce, limiting the understanding of potential exposure scenarios. In this context, the present study investigates the occurrence, concentration and co-occurrence of pesticide residues in tomatoes collected from major tomato-producing regions across Albania, while also assessing their potential implications for consumer safety. Quantitative analysis was carried out using validated methods based on complementary advanced chromatography techniques, providing a broad analytical coverage of pesticides from multiple chemical classes. Residue levels were evaluated against established maximum residue limits (MRLs), and dietary exposure was estimated to assess potential chronic and acute risks to consumers. The co-occurrence of several active substances within individual samples was frequently observed, reflecting intensive pest-management practices in tomato cultivation. Although the majority of detected residues were below their respective MRLs, a limited number of samples contained pesticide concentrations approaching or exceeding regulatory thresholds, indicating potential food safety concerns. Risk assessment results suggested that overall consumer exposure was generally within acceptable limits; however, certain pesticides may contribute disproportionately to dietary intake, particularly under high-consumption scenarios. Overall, this study provides updated and risk-relevant evidence on pesticide contamination patterns in Albanian tomatoes and highlights the need for sustained residue monitoring, improved farmer training on responsible pesticide application, and strengthened regulatory oversight to reduce dietary exposure and strengthen consumer protection.

Keywords: Pesticide residues, Food Safety, Multi-residue methods, Risk assessment, tomatoes, MRL.

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THE ESTIMATION OF TOTAL NITROGEN LEVELS BY THE KJELDAHL METHOD AND SOME PHYSICOCHEMICAL PARAMETERS IN AGRICULTURAL LANDS: CASE STUDY ANADRINIA REGION-KOSOVO

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ABSTRACT

Determining soil health indicators, especially total soil nitrogen, is an important and challenging task that affects farmers' decisions about the timing, placement and number of fertilisers applied on farms. Most of the existing methods for measuring total Nitrogen are stoichiometric or spectroscopic-based analytical chemistry laboratory methods, which require considerable human input and effort, consume time, are expensive, and low-processing in nature. For this research, we have used the Kjeldahl method. As it is known, Dukagjini is an area that contributes mostly to agricultural production in Kosovo. Therefore, the purpose of this research was to determine the total nitrogen and some physico-chemical parameters in the agricultural lands of the Dukagjini area, specifically in the Municipality of Rahovec and Deçan, to determine the quality of the agricultural land. The study was carried out in the Spring season, before the crops, where soil samples were taken from several different localities of the region. The samples were taken in Alluvial, Deluvial, Smonic and light reddish soils, at a depth of 0-20 cm, then the same were treated and analyzed according to standard soil procedures. The parameters measured in these samples are mainly basic physico-chemical parameters such as: total nitrogen, pH, humidity, conductivity, humus, as well as the determination of carbonates.

Keywords: Total nitrogen, agricultural soil, Dukagjini, Deçani, Rahoveci, plant products, physico-chemical parameters.

FLORISTIC DIVERSITY EVALUATION IN THE STEPPE REGION OF KSAR CHELLALA, TIARET, ALGERIA

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ABSTRACT

Our study focuses on the native vegetation of the KSAR CHELLALA region, using a phytocological approach that includes an analysis of climate, soil, and vegetation. The climate analysis reveals a clear aridification of the region, with insufficient precipitation and high sun exposure, rendering the area arid. It is also important to note that anthropogenic factors contribute to the degradation of the area. The floristic inventory conducted during the year 2022-2023 across seven stations reveals the presence of 68 taxa distributed in 17 families and 55 genera. Among these families, Asteraceae are particularly well-represented and well-adapted to the local conditions. The soil analysis indicates that our area is characterized by infertile soil with a high limestone content and alkaline pH, favoring the presence of abundant calcicolous vegetation. Correspondence Analysis (C.A.) allows us to understand the interrelationships between plant species, revealing a gradual transition from the steppe-type vegetation to pre-Saharan vegetation. Therefore, it is crucial to protect this plant diversity before it is lost.

Keywords: native plants, floristic inventory, Ksar Chellala region, climate, soil.

DEVELOPING EXPERIENTIAL CLASSROOMS TOWARD SUSTAINABLE EDUCATION

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ABSTRACT

This study examines the educational value of school trees and green learning environments in promoting experiential learning and sustainable education in Vietnamese schools. A mixed-methods research design was employed, combining quantitative surveys and qualitative interviews. The study involved 180 lower secondary students from three schools in Hanoi and 12 teachers responsible for environmental and experiential education activities. Students participated in school tree-based activities including observation, measurement, collaborative discussions, and STEM-related environmental projects. Quantitative data were analyzed using descriptive statistics, independent sample t-tests, and one-way ANOVA, while qualitative data were examined through thematic analysis. The findings revealed positive student perceptions regarding learning engagement, environmental awareness, experiential learning, and sustainability attitudes. Significant differences were identified across gender and grade levels. Qualitative findings further indicated that teachers viewed school trees as meaningful educational resources supporting authentic learning experiences. The study suggests that transforming school green environments into experiential classrooms may represent an effective and practical approach for promoting sustainable education in Vietnam.

Keywords: experiential learning; school trees; sustainable education; environmental education; STEM education; Vietnamese schools.

THE IMPACT OF EDUCATIONAL PROGRAM IN THE RELATIONSHIPS AND PROFESSIONAL BEHAVIOUR OF NURSES IN COLLABORATION WITH MEDICAL STAFF

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ABSTRACT

Professional behavior is defined as conduct in accordance with the technical and ethical standards of a profession. Acting in a professional manner means being polite, having good communication, and remaining calm in all circumstances.[1] Professionalism, as defined by Business Dictionary, is: „The consistent application of courtesy, honesty, and responsibility by an individual in their relationships with clients and colleagues, along with a level of excellence that goes beyond commercial considerations and legal requirements.” The purpose of the project is to assess the professional relationships of nurses with their colleagues, identify the issues within these relationships and their impact on the delivery of healthcare services, and to provide the necessary recommendations for improving professional behavior and the performance of nurses in the workplace in the city of Vlora. Methodology: The study includes the implementation of an educational program for staff, focusing on the development and improvement of professional relationships. After the completion of the program, changes in staff knowledge and professional behavior will be evaluated, analyzing the effects of the education on nurse–nurse and nurse–physician relationships. This project aims to provide valuable data for enhancing interdisciplinary collaboration and improving the quality of healthcare. Result: Nurses’ relationships with colleagues are rated at an average level. Relationships with fellow nurses need improvement, as professional behavior and ethics remain at moderate levels. The professional relationship between nurses and medical staff is also perceived as average. Three main factors perceived as sources of difficulty in the nurse–physician relationship are hierarchy, communication among staff, and adherence to ethical rules [2,13,14,15,16,17]. The educational program improved teamwork and communication, reducing conflicts and stress while increasing efficiency and staff satisfaction [2,3,4,5,6]. More harmonious professional relationships contribute to a more stable work environment and to the delivery of high-quality healthcare. Conclusions: The interventions implemented during the execution of this project have had significant results in improving professional relationships between nurse–nurse and nurse–physician. Recommendations: Practicing a highly professional performance and maintaining professional relationships between nurse–nurse and nurse–physician. Ensuring communication and professional ethics through the use of appropriate medical terminology. Promoting collaboration and completing tasks as a team. Respecting professional hierarchy. Implementing and mutually respecting the competencies of nurses and physicians in order to provide high-quality and optimal patient care.

Keywords: Professional relationships, nurse, physician, identification, factors, causes, education, analysis, evaluation, Vlora Regional Hospital.

A GWO-POWERED MULTI-SOLVER META-DECISION FRAMEWORK FOR LARGE-SCALE SUSTAINABILITY BENCHMARKING OF MEDITERRANEAN HOSPITALITY INFRASTRUCTURE

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ABSTRACT

The benchmarking and selection of sustainable hospitality infrastructure represent a complex decision-making challenge characterized by highly conflicting operational, environmental, financial, and socio-economic dimensions. While Multi-Criteria Decision-Making (MCDM) methods are widely used to navigate these trade-offs, they frequently suffer from algorithmic rank divergence, where different mathematical solvers produce contradictory rankings on identical datasets. To address this challenge and eliminate subjective weighting biases, this paper introduces a scalable, macro-scale meta-decision framework. Criteria weights are objectively extracted directly from the multi-attribute data matrix using the Grey Wolf Optimizer (GWO). These optimized weights are then anchored across an extensive parallel portfolio of thirteen autonomous MCDM methods (spanning distance-based, utility-maximizing, outranking, and compromise-seeking families, including VIKOR, TOPSIS, MOORA, GRA, COPRAS, SAW, ELECTRE, PROMETHEE, ANP, WASPAS, TODIM, Pluie, and WPM) executed concurrently. The framework is empirically validated on a high-dimensional dataset comprising 947 sustainable facilities across 10 Mediterranean nations evaluated against 23 performance criteria. To verify the reliability of the prescriptive outcomes, a rigorous tripartite validation architecture is established: cross-methodological consensus mapping via Borda points and Jaccard similarity indices, structural rank stability stress-testing using 10,000 stochastic Monte Carlo simulation iterations, and absolute efficiency verification via strict multi-objective Pareto non-domination boundary checks. The results demonstrate that the framework successfully mitigates method-dependency risks, identifies robust and stochastically stable consensus alternatives, and provides an evidence-based guideline for large-scale sustainable asset management and decision support systems.

Keywords: Multi-Criteria Decision-Making (MCDM), Grey Wolf Optimizer (GWO), Algorithmic Rank Divergence, Sustainable Hospitality, Monte Carlo Simulation; Pareto Efficiency.

ENVIRONMENTAL PROTECTION EDUCATION THROUGH PROJECT-BASED LEARNING: DESIGNING MUSICAL INSTRUMENTS FROM RECYCLED MATERIALS BY PRESERVICE TEACHERS

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ABSTRACT

Environmental protection has become a central concern in contemporary education due to escalating environmental degradation and the urgent need for sustainable development. In teacher education, equipping preservice teachers with environmental awareness, responsibility, and pedagogical competence is particularly important, as they play a key role in shaping future generations' attitudes toward environmental protection. This study investigated the effectiveness of environmental protection education implemented through project-based learning, focusing on the design of musical instruments from recycled materials by preservice teachers in Vietnam. A mixed-method research design was employed, involving 247 preservice teachers and 15 lecturers from five higher education institutions. Quantitative data were collected through questionnaires measuring environmental awareness, creativity, learning engagement, and perceptions of project-based learning effectiveness, while qualitative data were obtained from semi-structured interviews with lecturers. The results indicated that project-based learning significantly enhanced preservice teachers' environmental awareness, sense of environmental responsibility, creative thinking, and learning engagement. Lecturers' perspectives further confirmed the pedagogical value of integrating recycled-material design into teacher education, highlighting increased student motivation, interdisciplinary learning, and practical relevance, despite challenges related to time and assessment. The findings suggest that project-based learning centered on recycled materials provides an effective approach to environmental protection education in preservice teacher training and offers practical implications for integrating sustainability-oriented pedagogy into higher education curricula.

Keywords: environmental protection education, project-based learning, recycled materials, musical instrument design, preservice teachers, sustainability education.

PSEUDOMONAS-MEDIATED ALLEVIATION OF SALT STRESS IN VICIA FABA: RHIZOBACTERIAL ENHANCEMENT OF GERMINATION AND IMPLICATIONS FOR SUSTAINABLE AGROECOSYSTEMS

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ABSTRACT

Soil salinity poses significant environmental challenges to plant life, affecting all organs and developmental stages. Osmotic stress is the primary mechanism by which salinity impairs seed starch hydrolysis and embryo emergence during germination. Plant growth-promoting rhizobacteria (PGPR) inoculation, especially *Pseudomonas* species, has gained interest for mitigating abiotic stress effects. This study investigated the effect of rhizospheric *Pseudomonas* on the germination of two *Vicia faba* varieties (Aguadulce and a local Algerian variety) under saline conditions. Seeds were surface-sterilized and imbibed in distilled water (control) or NaCl solutions (100 or 200 mM), with or without bacterial inoculation (three selected strains). Germination percentage, speed, and mean germination time (T_{50}) were recorded over nine days at 25 °C. Salinity reduced germination percentage and delayed germination in both varieties. In non-saline conditions, bacterial inoculation enhanced germination percentage but also increased T_{50} . Under salt stress, *Pseudomonas* strains significantly improved germination percentage and speed in the Aguadulce variety, but not in the local variety. Among strains, SHA21 was most effective for Aguadulce seeds under salinity. These results suggest that PGPR inoculation can enhance the salt tolerance of *V. faba* seeds, with varietal differences in responsiveness. Beyond immediate agronomic outcomes, these findings carry broader implications for sustainable legume cultivation: *Vicia faba*'s capacity for biological nitrogen fixation, its role in fostering soil microbiome diversity, and its value as a pollinator resource position it as a keystone species for agroecosystem biodiversity and sustainable development.

Keywords: PGPR, *Pseudomonas*, seed germination, *Vicia faba*, salt stress, biodiversity, sustainable agriculture.

FROM PREDICTION TO OPTIMIZATION: MACHINE LEARNING AND GENETIC ALGORITHMS FRAMEWORK FOR AGRO- ECOSYSTEM MANAGEMENT

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ABSTRACT

This study presents an integrated framework for agro-ecosystem decision support that combines machine learning-based crop-yield prediction with Genetic Algorithm (GA)-based optimization of controllable farm-management variables. Preliminary experiments on the original simulated dataset showed weak learnable structure and predictive performance close to a naive baseline. To address this limitation, a crop-aware synthetic dataset was constructed for methodological validation, expanding the data from 500 to 1,030 observations across five crop types. The dataset introduced a more coherent agronomic response structure linking soil, climate, vegetation, management, and disease factors to crop yield. The analysis included several tree-based ensemble models, such as Random Forest and Extra Trees, as well as boosting methods including Gradient Boosting, XGBoost, and CatBoost. The best-performing pipeline, EnhancedCatBoostLog, achieved a test MAE of 235.73, RMSE of 295.56, and R2 of 0.9358. The optimization stage focused on soil moisture, soil pH, pesticide usage, irrigation type, and fertilizer type, while maintaining sunlight exposure as a fixed environmental input. A five-fold GA evaluation using repeated model retraining and fold-level test samples yielded an average improvement of 263.90 kg/ha, corresponding to 12.38%, with positive gains in 97.5% of cases. These results show the methodological potential of integrating predictive modeling and resource-aware optimization for agro-ecosystem management under controlled synthetic conditions.

Keywords: Smart agriculture, agro-ecosystem management, machine learning, genetic algorithm, crop yield prediction, decision support.

DISTRIBUTION AND RECORDING OF FLORAL VISITS BY TWO BUMBLEBEE SPECIES (HYMENOPTERA: APIDAE) IN SOME SITES OF THE TISSEMSILT REGION, ALGERIA

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ABSTRACT

Algeria, located in North Africa and forming part of the Maghreb, is the largest country bordering the Mediterranean Sea. This country enjoys a favorable climate and possesses a rich floral diversity as well as an especially interesting fauna, including a great variety of wild bees. Bumblebees are common pollinators of both wildflowers and crops. Our study, conducted in western Algeria, specifically in the Tissemsilt region, focused on bees belonging to the tribe *Bombini* (Apidae) during the period of 2022 and 2023. This research enabled us to record two distinct species: *Bombus (Bombus) terrestris* (L., 1758) and *Bombus (Psithyrus) vestalis* (Geoffroy, 1785). We also observed the plants visited by these bees as well as their flight periods for each species. This is an original study, carried out for the first time in Algeria.

Keywords: North Africa, Taxonomy, *Bombus*, Ecosystem, Solitary Bees.

BRIDGING EDUCATIONAL GAPS TOWARD SUSTAINABLE DEVELOPMENT THROUGH LEGAL FRAMEWORKS: INTERNATIONAL EVIDENCE AND LESSONS FOR VIETNAM IN ENVIRONMENTAL PROTECTION EDUCATION

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ABSTRACT

Reducing educational gaps is a critical challenge for education systems seeking to achieve sustainable development. In recent years, environmental protection education has been increasingly recognised as a key component of education for sustainable development, with potential contributions not only to environmental awareness but also to educational equity and social inclusion. This study examines environmental protection education within legal frameworks as a tool for reducing educational gaps, drawing on international evidence and lessons for Vietnam. Employing a qualitative research design, the study combines a systematic literature review with comparative legal and policy analysis of international instruments and selected national experiences. The findings indicate that coherent legal frameworks, policy alignment between education and environmental sectors, and inclusive governance mechanisms are essential for the effective integration of environmental protection education into education systems. International experiences suggest that when environmental education is supported by clear legal recognition and participatory implementation, it can enhance learning relevance and contribute to more equitable educational outcomes. In Vietnam, although environmental protection education has been incorporated into education and environmental laws and policies, persistent regional and socio-economic disparities and implementation challenges remain. The study concludes that strengthening legal clarity, policy coordination, and equity-oriented educational management is necessary to maximise the role of environmental protection education in narrowing educational gaps towards sustainable development.

Keywords: Environmental protection education, legal frameworks, educational gaps, educational equity, education for sustainable development, Vietnam.

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INTEGRATED HYDROGEOCHEMICAL AND STRUCTURAL CONTROLS ON GROUNDWATER FLOW IN A SEMI-ARID GRABEN BASIN: CASE OF THE GHRISS PLAIN, NW ALGERIA

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ABSTRACT

The Ghriss Basin in northwestern Algeria is a tectonically controlled semi-arid intramontane basin hosting Plio-Quaternary aquifers that represent a key freshwater resource. This study examines the combined influence of tectonic structures, lithological variability, and hydrogeochemical processes on aquifer geometry, permeability distribution, and groundwater evolution. An integrated approach was applied, including geological and structural mapping, litho-structural zonation, fracture density analysis, hydrogeochemical characterization of 21 groundwater samples, and principal component analysis (PCA). The basin exhibits a graben structure bounded by NE–SW and E–W faults that control sediment thickness and groundwater flow pathways. Three hydrogeological domains were identified: permeable marginal alluvial deposits acting as recharge zones, a central low-permeability marly-lacustrine unit forming semi-confined conditions, and moderately fractured alluvial fans acting as preferential flow corridors. PCA shows that two main processes explain 66.1% of the total variance: mineralization driven by water–rock interaction and evaporation (PC1 = 46.8%), and recharge-related carbonate processes (PC2 = 19.3%). Strong correlations between EC and major ions (e.g., Cl^- , $r = 0.96$) indicate salinization along structurally controlled flow paths. Results highlight a heterogeneous and anisotropic aquifer system governed by fault-controlled connectivity. This study provides an integrated structural–hydrogeochemical framework for understanding groundwater evolution and supports sustainable groundwater management in semi-arid tectonic basins.

Keywords: Groundwater flow, Structural control, Hydrogeochemistry, Fracture networks, PCA, Semi-arid aquifer; Conceptual model.

WIND RESOURCE POTENTIAL ASSESSMENT AND TECHNO-ECONOMIC FEASIBILITY OF AN ONSHORE WIND FARM IN ALBANIA: MULTI-SCENARIO ANALYSIS FOR THE SHASHICA SITE, VLORA

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ABSTRACT

This paper presents a feasibility study for an onshore wind farm in the Shashica area, Vlora (Albania). Wind resource assessment was performed using the Wind Balkan Atlas (WBA), the New European Wind Atlas (NEWA), and the Wind Atlas Analysis and Application Program (WAsP), based on three years of on-site measurements from an anemometer tower, indicating a Class III wind resource. The optimal turbine type identified was the Vestas V163-4.5 MW (hub height 126 m). Four scenarios were developed, differing in the number of turbines installed (6 - 9 units). The economic performance of the project was assessed through key indicators, including LCOE, NPV, IRR, B/C ratio, and simple payback period (SPP), complemented by sensitivity analysis. The results showed that LCOE ranges from approximately 52.6 to 68.6 EUR/MWh depending on CAPEX, discount rate, and the number of turbines. The least favorable scenario yields an NPV of 0.9 million EUR (CAPEX = 1350 EUR/kW, discount rate = 11%, electricity price = 60 EUR/MWh, 9 turbines), while the most favorable scenario reaches approximately 48.4 million EUR (CAPEX = 1100 EUR/kW, discount rate = 5%, electricity price = 75 EUR/MWh, 9 turbines). The IRR varies from around 11.6% to 32%, while the best SPP is approximately 7 years. The sensitivity analysis confirmed that electricity sale price is the primary driver of project profitability, that NPV decreases with increasing discount rate, and that CAPEX directly affects the LCOE. Furthermore, the project could avoid approximately 81,465 tons of CO₂-eq emissions compared to a coal-fired power plant. The selection of the optimal scenario also depends on investor priorities and the prevailing economic, institutional, and financial conditions.

Keywords: wind farm, WAsP, feasibility study, sensitivity analysis, optimal scenario.

INTEGRATED ASSESSMENT OF BEACH QUALITY IN THE ALBANIAN COASTLINE USING THE BEACH QUALITY INDEX (BQI)

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ABSTRACT

The purpose of this study to evaluate the environmental quality of eight representative beaches along the Albanian Adriatic coastline using the Beach Quality Index (BQI), based on recreational, natural, and protective functions. The assessment was conducted during the summer seasons of 2023–2024 at Velipojë, Shëngjin, Durrës, Gjiri i Lalzit, Kavajë, Qerret, Spille, and Vlorë beaches. The BQI methodology incorporated indicators related to microbiological bathing water quality, environmental quality, services and facilities, overcrowding, accessibility, pollution events, and coastal protection capacity. Descriptive statistics, Wilcoxon signed-rank tests, and Pearson correlation analysis were performed. The results indicated moderate recreational quality across most beaches, with Recreational Function Index (RFI) values ranging from 0.30 to 0.55. Semi-urbanized beaches such as Gjiri i Lalzit and Spille recorded the highest Natural Function Index (NFI) and overall BQI values due to better-preserved ecological conditions and lower anthropogenic pressure. Protective Function Index (PFI) values remained relatively low across most sites, indicating limited resilience against coastal erosion and wave impacts. Gjiri i Lalzit recorded the highest BQI values (0.79–0.80). Statistical analysis showed no significant differences between the two assessment periods ($p > 0.05$), while Pearson correlation analysis demonstrated a strong positive correlation between BQI and RFI ($r = 0.806$; $p < 0.05$). The study demonstrates that BQI is an effective tool for integrated coastal assessment and sustainable beach management.

Keywords: Beach Quality Index, recreational beaches, coastal management, bathing water quality, Adriatic coast, environmental assessment.

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ENVIRONMENTAL DRIVERS OF BRYOPHYTE DIVERSITY AND COMMUNITY ASSEMBLY IN THE SEMI-ARID MEDITERRANEAN ECOSYSTEMS OF THE TIARET REGION, ALGERIA

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ABSTRACT

This study provides a comprehensive floristic inventory and ecological assessment of bryophytes in the Tiaret region of northwestern Algeria, a semi-arid Mediterranean area characterized by marked climatic variability and habitat heterogeneity. Systematic field surveys were conducted across multiple sites during the winter and spring seasons, leading to the identification of 42 bryophyte taxa. The recorded flora is dominated by mosses, while liverworts exhibit low species richness and hornworts are absent. Taxonomically, all identified taxa belong to two major classes. The class Bryopsida is the most diversified group, encompassing 34 taxa distributed across multiple families. The second class, Hepaticopsida, is represented by two subclasses: Marchantiopsida, comprising five families (Lunulariaceae, Oxymitracaceae, Aytoniaceae, Ricciaceae, and Targioniaceae), and Jungermanniopsida, represented solely by the family Fossombroniaceae. Ecological analyses reveal a clear pattern of species richness concentration in humid microhabitats, highlighting the strong dependence of bryophyte distribution on water availability. Multivariate analysis (CCA) further indicates that substrate type and moisture are the primary environmental drivers structuring bryophyte assemblages, while altitude exerts a secondary but still significant influence. Overall, these results emphasize the strong ecological sensitivity of bryophytes to microclimatic conditions in semi-arid ecosystems. The observed low representation of liverworts and the absence of hornworts reflect their limited tolerance to aridity and environmental stress. This study provides new baseline data on bryophyte diversity in northwestern Algeria and contributes to a better understanding of their ecological behavior under Mediterranean semi-arid conditions.

Keywords: Bryophytes, species inventory, semi-arid ecosystems, microhabitat humidity, Tiaret, Algeria, ecological distribution.

BIBLIOMETRIC ANALYSIS OF GLOBAL RESEARCH TRENDS AND HOTSPOTS IN SWEET CHERRY STUDIES DURING 2005-2024

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ABSTRACT

Sweet cherry (*Prunus avium* L.) is an economically important fruit crop widely studied for its genetic diversity, fruit quality, yield, disease resistance, and adaptation to changing environmental conditions. The increasing number of scientific publications on this species highlights the need for a systematic assessment of research development, influential contributors, collaboration patterns, and emerging research hotspots. This study aimed to analyze global research trends and the evolution of themes in sweet cherry studies published between 2005 and May 2024. A bibliometric analysis was conducted using 466 research articles and review papers retrieved from the Dimensions AI database. VOSviewer was used to visualize annual publication trends, keyword co-occurrence, citation patterns, co-citation networks, and international collaborations. The analysis focused on publication output, leading countries and institutions, frequently used keywords, thematic shifts, and highly cited studies. The results showed a general increase in publication output over time, with the highest number of papers published in 2023. The United States, China, Italy, Spain, and Turkey were the leading contributors, with 178, 109, 46, 39, and 36 publications, respectively. Keyword analysis revealed a shift from production-related, morphological, pomological, and propagation-oriented studies toward research on genetic diversity, population structure, molecular markers, and genomics-assisted breeding. Recent studies have increasingly emphasized marker-assisted selection, genomic tools, improvements in fruit quality, germplasm conservation, and resilience to biotic and abiotic stresses. Overall, this study provides a comprehensive overview of publication patterns, major contributors, citation trends, collaboration networks, and the thematic evolution of sweet cherry research.

Keywords: Bibliometric analysis, sweet cherry, research trends, VOSviewer.

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SYNTHESIS, *IN SILICO* EVALUATION, AND PRELIMINARY CYTOTOXIC ASSESSMENT OF NOVEL QUINAZOLINE-ISATIN HYBRIDS AS POTENTIAL VEGFR INHIBITORS AGAINST HEPATIC CANCER CELLS

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ABSTRACT

An evaluation of the synthetic route to derive new quinazoline-isatin hybrids as potential inhibitors of vascular endothelial growth factor receptor 2 (VEGFR-2) in the treatment of liver cancer, and an assessment of the preliminary cytotoxicity was undertaken. The derivatives were synthesized through a hydrazine-mediated conversion of ethyl 4-oxo-3,4-dihydroquinazoline-2-carboxylate to the corresponding intermediate hydrazide, followed by the condensation with different isatin derivatives to give five target derivatives, H1–H5. Characterization of the structure of the new target derivatives was confirmed using FT-IR, ¹H--NMR and ¹³C-NMR spectroscopy. Drug-likeness and ADME evaluations revealed that all target hybrid derivatives had acceptable oral drug-likeness properties, good GI absorption, and complied with Lipinski's Rule of Five. The newly synthesized derivatives docked in the active site of the VEGFR2 receptor (PDB: 4AG8) showed good fit within the ATP binding site, with H5 and H1 having the best binding scores with important interactions with the conserved residues Cys919, Asp1046, and Phe1047. The results of initial cytotoxicity tests (MTT assay) performed on HepG-2 and WRL-68 cell lines indicated that the two quinazoline-isatin hybrids H2 and H5 showed the highest level of selective antiproliferative activity. Based on these data, H2 and H5 represent the most promising candidates for optimization and additional biological evaluation for potential use as anti-angiogenic anticancer agents.

Keywords: ADME, cytotoxicity, isatin, liver cancer, molecular docking, quinazoline, VEGFR.

ADVANCING TRANSBOUNDARY CONSERVATION AND SUSTAINABLE DEVELOPMENT IN THE PRESPA LAKES REGION: INTEGRATING GOVERNANCE, POLICY, AND COMMUNITY-DRIVEN STRATEGIES

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ABSTRACT

The Prespa Lakes, shared by Albania, Greece, and North Macedonia, constitute a globally significant transboundary freshwater ecosystem, hosting endemic fish, rare flora, and migratory birds such as the Dalmatian Pelican. Decades of unsustainable agricultural practices, overfishing, habitat degradation, and climate variability have eroded ecological resilience, while socio-economic pressures - including population decline and uneven tourism development - further challenge sustainable management. The Prespa Strategic Action Plan (SAP) 2025–2030 presents an integrated framework linking adaptive ecosystem management, sustainable livelihoods, and participatory, community-driven governance. Through legal and policy assessment, institutional analysis, stakeholder consultations, and environmental and socio-economic evaluation, structural gaps are identified, and opportunities for transboundary collaboration are highlighted. Strategic interventions include governance reform, water and ecosystem conservation, sustainable development initiatives, and public engagement programs. Lessons from the Prespa SAP demonstrate that adaptive, science-informed, and participatory approaches are essential to reconcile ecological protection, economic resilience, and cross-border governance in complex freshwater systems.

Keywords: Prespa Lakes, transboundary conservation, adaptive management, governance, sustainable livelihoods, biodiversity, Strategic Action Plan 2025–2030.

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DESIGN, SYNTHESIS, *IN SILICO* EVALUATION, AND PRELIMINARY CYTOTOXIC ASSESSMENT OF NOVEL QUINAZOLINE DERIVATIVES AS POTENTIAL EGFR INHIBITORS AGAINST PANCREATIC CANCER CELLS

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ABSTRACT

A new generation of quinazoline analogs with benzaldehyde and acetophenone functional groups were developed and produced as a possible EGFR-targeted antinoplastic agent in the treatment of pancreatic cancer. The design plan was relying on the maintenance of the quinazoline scaffold as the nucleus, with structural modification through structural modification with the chosen aromatic aldehyde and ketone derivatives. Physicochemical properties and spectral analyses (FT-IR, ¹H-NMR, and ¹³C-NMR) were used to characterize the synthesized compounds. They were assessed by SwissADME to determine their drug-likeness and pharmacokinetic characteristics, and generally acceptable profiles with adherence to Lipinski rules, high likelihood of gastrointestinal absorption, and no predicted P-glycoprotein substrate liability. Molecular docking with the EGFR kinase domain (PDB ID: 3W33) revealed positive binding of all the synthesized derivatives with docking scores of -7.50 to -8.62 kcal/mol and maintains the interaction with a key hinge region with Met793. Among the compounds tested, CP6 had the highest docking score, thus it was used to simulate a molecular dynamic that confirmed the stability of its complex with EGFR. Preliminary cytotoxic activity was evaluated by the MTT assay against AsPC-1 and Capan-2 pancreatic cancer cell lines utilizing erlotinib as the reference drug. Among the synthesized derivatives, CP3 showed the most favorable biological activity, with IC₅₀ values of 39.69 μM and 48.20 μM versus AsPC-1 and Capan-2, respectively, followed by CP6 with IC₅₀ values of 41.98 μM and 51.69 μM. In sum, the present findings identify CP6 as the lead computational candidate while CP3 as the lead biological candidate, supporting the potential of this quinazoline series for ongoing development as EGFR-targeted antinoplastic agents.

Keywords: quinazoline, pancreatic cancer, molecular docking, adme, molecular dynamics simulation, cytotoxicity, EGFR.

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ENVIRONMENTAL RESPONSIBILITY AND ECOLOGICAL CITIZENSHIP: A PHILOSOPHICAL FRAMEWORK FOR ECOSYSTEM PROTECTION THROUGH JONAS, LEOPOLD, AND DOBSON

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ABSTRACT

The contemporary ecological crisis reveals the limits of purely technical, economic, and administrative responses to ecosystem degradation. Climate change, biodiversity loss, soil degradation, water pollution, and habitat fragmentation are not only environmental problems; they are also ethical and civic challenges that require a reconsideration of the human relationship with the natural world. This article develops a philosophical framework for ecosystem protection through the works of Hans Jonas, Aldo Leopold, and Andrew Dobson. Jonas's ethics of responsibility provides a future-oriented moral foundation by emphasizing the long-term consequences of modern technological power. Leopold's land ethic expands the moral community beyond human beings and includes soils, waters, plants, animals, and ecological relations within the sphere of ethical concern. Dobson's theory of ecological citizenship translates environmental responsibility into civic and political obligations that extend beyond national borders and present generations. By bringing these three perspectives together, the article argues that ecosystem protection should be understood as a shared ethical and civic responsibility. The protection of ecological integrity requires not only scientific knowledge, regulation, and environmental management, but also a transformation in how responsibility, citizenship, and moral community are understood. This article contributes to environmental ethics by proposing an integrated framework in which future responsibility, land-community ethics, and ecological citizenship form the normative basis for ecosystem protection.

Keywords: environmental responsibility; ecological citizenship; ecosystem protection; environmental ethics.

ECO-SOCIAL WORK AND ECOSYSTEM SUSTAINABILITY: A FRAMEWORK FOR COMMUNITY RESILIENCE AND ENVIRONMENTAL JUSTICE IN VULNERABLE POPULATIONS

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ABSTRACT

In the contemporary era, ecosystem degradation, industrial pollution, and urban climate vulnerability have transitioned beyond environmental boundaries to become acute socioeconomic crises. Vulnerable populations, specifically low-income families and marginalized youth, suffer disproportionately from ecological disequilibrium. This study examines the intersection of social work and ecosystem sustainability within the urban-industrial corridor of Central Albania (Tirana, Elbasan, and Durrës). Operating under the theoretical paradigms of Green Social Work and Ecological Systems Theory, the paper addresses the impact of environmental degradation on human psychosocial well-being. A mixed-methods research design was deployed, incorporating a quantitative survey (N = 120 vulnerable families) and qualitative focus groups (N = 3) with social work practitioners. The empirical findings indicate a robust correlation between systemic ecosystem degradation (air pollution, lack of urban green spaces, and waste mismanagement) and heightened psychosocial stress, compounding existing socioeconomic vulnerabilities. The paper delineates an integrated eco-social intervention framework, arguing that modern social work must incorporate ecological literacy and environmental advocacy into its core practice to foster sustainable community resilience and environmental justice.

Keywords: eco-social work, ecosystem sustainability, environmental justice, community resilience, central Albania.

DEVELOPMENT OF AN AI-BASED REAL-TIME DRAGONFLY SPECIES IDENTIFICATION SYSTEM

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ABSTRACT

The advancement of artificial intelligence and the increasing availability of open biodiversity datasets have significantly transformed ecological monitoring methodologies. With this development we present a real-time dragonfly species identification system based on latest AI deep learning techniques. The system implementation is made in two steps. The first is Python development which integrates multiple modern libraries, including pandas for data manipulation, PIL for image processing, Folium for geospatial visualization, Streamlit for user integration and PyTorch for model development. The second is a client-side browser-based development built onto lightweight Tensorflow libraries. The Global Biodiversity Information Facility (GBIF) is used as the dataset for this project. It is one of the most complete datasets and provides a lot of useful features. One amazing feature is structured biodiversity data. With this feature we can use taxonomic classifications to organize species, geospatial coordinates to find the exact location of identified species, and image references that point to images. Two convolutional neural network (CNN) architectures, ResNet18 and EfficientNet-B0, are employed to perform species classification tasks. These architectures are selected due to their efficiency and strong performance in image recognition problems. The trained models are first optimized in Python development. At the moment, Python libraries do not offer direct export from PyTorch to Tensorflow, instead we export to a more general format like ONNX, and then from ONNX to Tensorflow. Tensorflow offers a formidable way to make real-time inference directly within web browsers. In addition it eliminates the need for high end devices on the server-side for computation, and ensures low latency. From our test results we noticed that EfficientNet-B0 achieves high classification accuracy up to 98%, while ResNet18 offers faster inference speed. The results show that we can use them in different real-time scenarios, depending on what matters the most: speed or accuracy. The proposed system provides a scalable and accessible solution for biodiversity monitoring and contributes to the advancement of AI-driven ecological tools.

Keywords: artificial intelligence, Tensorflow, ONNX, ResNet18.

IMPACT OF ARBUSCULAR MYCORRHIZAL FUNGI ON THE MACROELEMENTS UPTAKE IN DIFFERENT SUBSTRATE OF BLUEBERRY (*VACCINIUM CORYMBOSUM* L.)

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ABSTRACT

This study evaluated the influence of arbuscular mycorrhizal fungi (AMF) on the uptake of macroelements—nitrogen (N), phosphorus (P), and potassium (K)—in highbush blueberry (*Vaccinium corymbosum* L.) cultivar ‘Draper’ grown in replanted and virgin substrates. Plants were cultivated in substrates previously used for blueberry production for ten years as well as in non-cultivated substrates. Mycorrhizal inoculation significantly altered nutrient availability and uptake in both substrate types. In replanted substrates, AMF application increased nitrate nitrogen (N-NO_3^-) content from 9.3% in the control to 31.2%, while ammonium nitrogen (N-NH_4^+) decreased markedly from 3.94% to 1.13%. In virgin substrates, N-NO_3^- concentration rose from 7.1% to 13.5% following AMF inoculation, whereas changes in N-NH_4^+ were minor (1.6% in the control and 1.4% in AMF-treated plants). Moreover, lower concentrations of P (4.8%) and K (8.1%) were recorded in mycorrhizal substrates compared to the control (5.3% and 9.8%, respectively). The results indicate that AMF significantly modified macroelement dynamics by reducing substrate N-NH_4^+ , P, and K contents while enhancing N-NO_3^- availability. Additionally, mycorrhization promoted higher accumulation of nitrogen and potassium in blueberry leaves, confirming the beneficial role of AMF in improving nutrient uptake efficiency under both replanted and virgin substrate conditions.

Keywords: Macroelements, Virgin substrate, Replanted s substrate, Mycorrhizal fungi, *Vaccinium corymbosum*.L.

HPLC-DAD-UV PHYTOCHEMICAL ANALYSIS AND EVALUATION OF ANTIOXIDANT AND ANTI-INFLAMMATORY ACTIVITIES OF *THAPSIA GARGANICA* ROOT AND FRUIT EXTRACTS FROM THE TIARET REGION, ALGERIA

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ABSTRACT

Thapsia garganica is traditionally used in North Africa for the treatment of rheumatic pain, eczema, and respiratory disorders; however, its antioxidant and anti-inflammatory potential remains insufficiently documented, particularly in the Tiaret region of Algeria. HPLC-DAD-UV analysis allowed the identification of eleven metabolites in root extracts and eight in fruit extracts. Quantitative analysis revealed higher total phenolic, flavonoid, and condensed tannin contents in the fruit extract. Antioxidant activity was assessed using DPPH and FRAP assays. The fruit extract exhibited stronger radical scavenging activity ($IC_{50} = 2.73$ mg/mL) compared to the root extract ($IC_{50} = 12.09$ mg/mL), while both extracts showed moderate ferric-reducing capacity. Anti-inflammatory activity was evaluated through erythrocyte membrane stabilization *in vitro* and carrageenan-induced paw edema *in vivo*. The root extract demonstrated superior membrane stabilization ($IC_{50} = 10.35 \pm 1.23$ mg/mL) compared to the fruit extract ($IC_{50} = 15.96 \pm 0.24$ mg/mL). Acute toxicity testing indicated significant toxicity at high doses (300–500 mg/kg). These findings highlight the distinct bioactivities of root and fruit extracts and support the potential of *T. garganica* as a promising source of bioactive compounds with antioxidant and anti-inflammatory properties.

Keywords: *Thapsia garganica*, HPLC-DAD-UV, antioxidant activity, anti-inflammatory, histopathology.

SCREENING SEEDLING ROOT ARCHITECTURE IN *TRITICUM TURANICUM* AND *TRITICUM POLONICUM* ANCIENT WHEAT SPECIES

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ABSTRACT

Wheat (*Triticum* spp.) provides about one-fifth of global calories, yet modern cultivars possess a narrow genetic base, making the exploration of ancient tetraploid relatives such as *Triticum turgidum* ssp. *turanicum* and *T. turgidum* ssp. *polonicum* essential for uncovering valuable root and shoot traits to enhance climate resilience. This study aimed to characterize early-stage seminal root and shoot traits across a diverse panel of 25 genotypes, including modern bread wheats (*T. aestivum*), durum wheats (*T. durum*), *T. turanicum*, and *T. polonicum*, using a germination-paper assay under controlled laboratory conditions for 15 days, with measurements of plant height, coleoptile length, rooting depth, seminal root number, root and shoot biomass, root/shoot ratio, and root/total biomass ratio. Analysis of variance revealed highly significant genotypic variation ($P < 0.001$) for all traits. Notably, *T. turanicum* PI481582 exhibited the longest coleoptile (10.3 cm) and PI 166554 the tallest plants (42.0 cm), indicating strong potential for deep-sowing tolerance, while *T. polonicum* PI 42209 achieved the deepest rooting (22.5 cm) and PI 192666 the highest root biomass (0.099 g). The modern durum variety Sırçalı demonstrated the highest root/shoot ratio (0.50) and root/total biomass percentage (33.4 %), reflecting superior early carbon allocation to roots, whereas modern bread wheats, despite having shorter coleoptiles, maintained moderate rooting depths. These findings confirm that ancient wheat relatives are exceptional genetic resources for improving early root vigour and deep-sowing adaptation, while modern durum cultivars exhibit efficient biomass partitioning, collectively offering promising breeding materials to develop climate-resilient, high-yielding wheat varieties for future agricultural systems.

Keywords: *Triticum polonicum*, *Triticum turanicum*, ancient wheat, genetic resources, root architecture.

UNLOCKING THE "HIDDEN HALF": ROOT PHENOTYPING OF KHORASAN AND POLISH WHEAT GENETIC RESOURCES

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ABSTRACT

Wheat root systems are critical for water and nutrient uptake, yet they remain an underexplored "hidden half" in breeding programs. Ancient wheat relatives may harbor valuable root traits for climate resilience. This study aimed to investigate phenotypic diversity in root and shoot traits among modern and ancient wheat genotypes (*T. aestivum*, *T. durum*, *T. polonicum*, and *T. turanicum*) during the stem elongation stage to identify genetic resources with superior root characteristics. Twenty-five wheat genotypes were grown in 100 cm PVC tubes under controlled greenhouse conditions. Root and shoot morphological traits were measured at the stem elongation stage, including rooting depth, biomass allocation, tiller number, and plant height. Significant genotypic differences ($P < 0.001$) were detected for all traits. *T. turanicum* accessions (Citr 11390 and PI 166308) displayed greater rooting depth than modern wheats and *T. polonicum* accessions. For root biomass, *T. polonicum* (PI 192666) and *T. turanicum* (PI 166450 and Citr 14082) accessions showed substantial root biomass accumulation relative to modern wheats. The hierarchical clustering dendrogram demonstrated a close association between traits, specifically grouping root biomass and shoot biomass within the same sub-cluster. Phenotypic grouping indicated a substantial extent of within-species plasticity. Ancient wheats, particularly *T. turanicum* and *T. polonicum*, offer valuable genetic resources for improving root architecture. Ancient wheats harbor valuable root traits that could be introgressed into modern varieties for wheat improvement. This study suggests that deep-rooting accessions are particularly advantageous for improving new varieties for rainfed conditions, whereas large-rooted accessions should be prioritized for yield evaluation, with the breeding goal of assessing their relative suitability under irrigated versus rainfed conditions.

Keywords: *Triticum* genetic resources, ancient wheat, root system architecture, phenotypic diversity, biomass allocation