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Perceptions of Ecosystem Services and Conservation: The Role of Gender and Education in Northeastern Algeria

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Abstract

Wetlands in northeastern Algeria's Numidia region provide vital ecosystem services, yet their cultural and intangible values (e.g., spiritual or aesthetic benefits) remain under-recognized in policy and practice. This study explores how gender, education, occupation, and wetland protection status influence local perceptions of provisioning, regulating, and cultural ecosystem services. Based on surveys ($n = 552$) across 12 wetland communities, results show that women place greater importance on cultural services, while those with higher education display more ecological awareness but less connection to traditional practices. Occupation and residence in protected areas also significantly shape valuation. These findings highlight the need for inclusive conservation strategies that integrate gender perspectives and local knowledge, promoting community-driven stewardship. This research supports more equitable and resilient environmental governance.

Keywords: biodiversity conservation; cultural services; ecosystem services; environmental education; gender differences; provisioning services; regulating services; sociodemographic factors



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1. Introduction

Global ecosystems face mounting pressures from climate change and human activities, disrupting species distributions, ecological interactions, and the delivery of vital ecosystem services (ESSs) upon which communities depend [1–5]. While these global pressures threaten ecosystems worldwide, wetlands in northeastern Algeria's Numidia region face unique challenges due to their ecological significance and socio-cultural context.

Northeastern Algeria's Numidia region hosts a diverse array of wetlands, including temporary pools, freshwater lakes, brackish marshes, and salines, which are vital for biodiversity and human well-being [6]. Recognized as a hotspot for freshwater biodiversity, these wetlands support rare and endemic species and serve as critical stopovers for migratory waterbirds [7]. Despite their ecological significance, Numidia's wetlands face mounting threats from deforestation, land-use change, and pollution, compounded by climate change impacts [5,8]. Formal protections, such as designations under the Ramsar

Convention and UNESCO's Man and the Biosphere Programme, provide a critical defense, yet local engagement remains essential for sustainable management. This study focuses on understanding local perceptions to inform culturally relevant conservation strategies in this unique socio-ecological context.

Ecosystem services (ESSs), encompassing provisioning (e.g., food, water), regulating (e.g., climate regulation, flood control), and cultural (e.g., spiritual, aesthetic) benefits, form a critical link between ecological health and societal well-being [1,2]. Research indicates that sociodemographic factors, such as gender, education, and occupation, shape how communities perceive and prioritize these services [9]. For instance, women often value regulating and cultural services tied to daily livelihoods, while men emphasize provisioning services linked to market values [10,11]. Education enhances ecological awareness but may reduce engagement in traditional practices [12,13]. In Algeria, prior studies suggest limited awareness of wetlands' ecological and cultural value, particularly in urban settings [14], highlighting the need to explore these dynamics in rural Numidian communities. Furthermore, changes in forest and wetland landscapes, whether through degradation or sustainable management, can significantly impact psychological well-being and community connection to nature, emphasizing the need to incorporate mental restoration into ecosystem service evaluations [15].

Research shows that men and women value ecosystem services differently: women often prioritize regulating and cultural services tied to daily livelihoods and social well-being while men focus more on provisioning services linked to market values [10,11].

Despite the ecological significance of Numidia's wetlands, local perceptions of their value, especially among different gender and educational groups, remain underexplored. Prior studies in Algerian urban contexts have shown that many residents perceive wetlands negatively, lacking awareness of their ecological and cultural importance [14]. These findings underscore the importance of environmental education and community-based engagement in shaping conservation behavior. This study addresses these gaps by examining how gender and education influence perceptions of ecosystem services in Numidia. By addressing these gaps, this study seeks to guide conservation strategies that integrate traditional knowledge and gender perspectives, fostering equitable and sustainable wetland management in Numidia. This study addresses gaps in understanding how sociodemographic factors shape perceptions of ecosystem services in Numidia's wetlands, a region of global ecological significance. By examining the influence of gender, education, occupation, and residence in protected areas, we aim to inform inclusive conservation strategies that integrate local knowledge and gender perspectives. This research aligns with global sustainability frameworks, such as the Millennium Ecosystem Assessment [1] and the IPBES [2], contributes to advancing SDG 5 (Gender Equality) and SDG 15 (Life on Land) by promoting equitable and community-driven environmental governance in Algeria.

2. Methods

2.1. Study Area

With a total area of nearly 2,382,000 km², Algeria is the largest country in Africa. Its northern boundary borders the Mediterranean Sea, while its southern frontier extends into the Sahara Desert. The coastal strip experiences a typical Mediterranean climate, characterized by hot, dry summers and mild, rainy winters. Northeastern Algeria hosts a rich variety of wetlands, ranging from temporary pools and shallow freshwater lakes to extensive brackish marshes and salines [6]. The region is traversed by lowland temporary rivers (wadis) and upland streams originating from the Atlas Mountains and the Hauts Plateaux.

Due to their ecological significance, particularly for migrating and breeding water-birds [7], many of these wetlands are protected as reserves, national parks, or under international agreements such as UNESCO's Man and the Biosphere (MAB) Programme and the Ramsar Convention. This formal protection remains the last line of defense against escalating anthropogenic pressures that threaten biodiversity and the provision of vital ecosystem services [8].

As part of this study, research was conducted across twelve wetlands in Numidia, northeastern Algeria, including nine protected and three unprotected sites, each supporting diverse assemblages of fauna and flora (Figure 1).

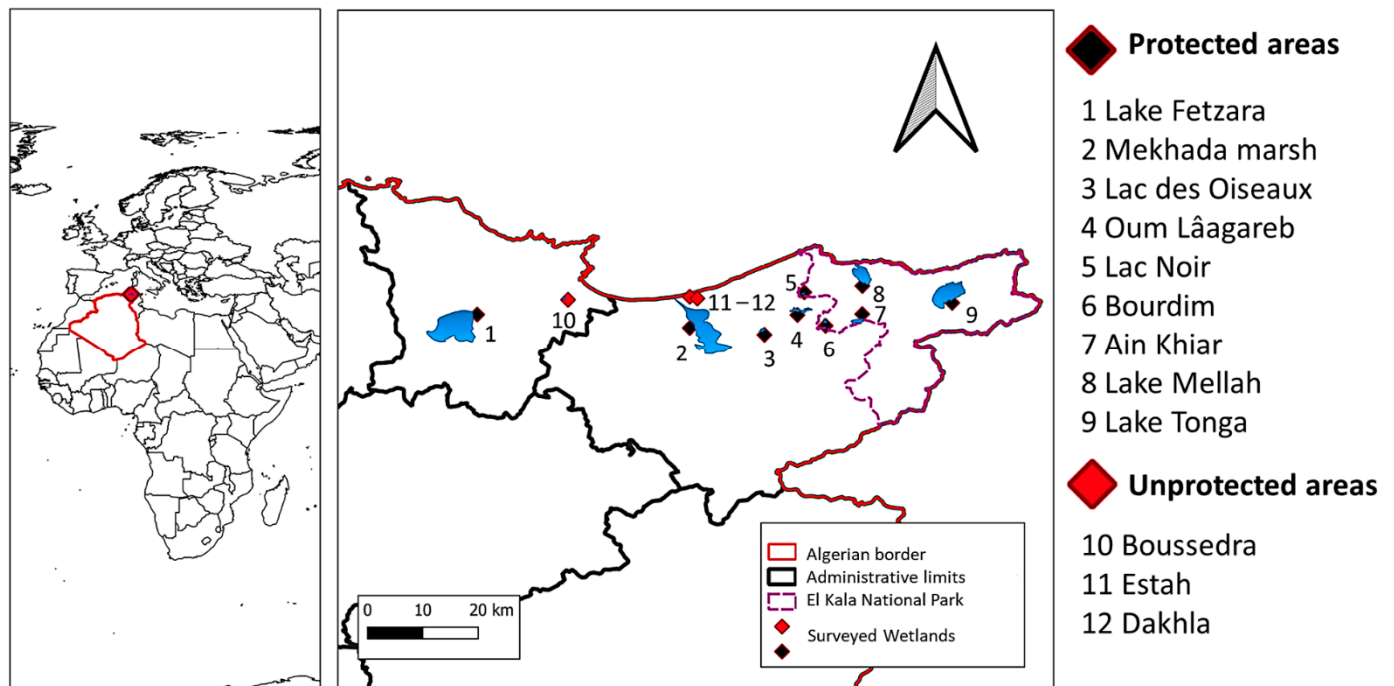


Figure 1. Map of northeastern Algeria with location of the study sites.

2.2. Survey Design and Data Collection

A comprehensive survey was designed to assess perceptions of three top-level ecosystem service (ES) categories, provisioning, regulating and maintenance, and cultural, following the Common International Classification of Ecosystem Services (CICES) v5.1 framework [16]. The survey included questions on usage frequency, perceived changes in availability and quality, the importance for well-being, policy adequacy, and management challenges (see Supplementary Materials File S1 for Provisioning Services, Supplementary Materials File S2 for Regulating Services, and Supplementary Materials File S3 for Cultural Services).

2.3. Sampling Strategy

The study employed a multi-level sampling technique [17], utilizing structured interviews based on a mixed-method questionnaire (combining open- and closed-ended questions) to collect data from communities directly experiencing and interacting with these ecosystem services. A representative random sample ($n = 597$) was collected using the following two distinct modes: face-to-face interviews, lasting approximately 10–15 min per respondent, and self-administered questionnaires, which were distributed and collected within a week. This dual approach ensured broad participation while accommodating respondents' preferences and availability.

The questionnaire was carefully designed to be accessible and user-friendly. Questions were constructed sequentially, with a focus on simplicity and clarity to avoid technical jargon, ensuring that respondents from diverse educational backgrounds could easily understand and respond without ambiguity [18,19]. Although no formal reliability coefficients (e.g., Cronbach's alpha) were calculated for this study, the questionnaire was adapted from instruments used in our prior research on biodiversity perception in Algeria [14,20]. These tools have been shown to effectively capture sociodemographic influences on environmental perception in Algerian contexts. Furthermore, the survey underwent additional pilot testing to ensure clarity, cultural relevance, and consistency with prior applications.

To further enhance comprehension, the questionnaire was translated into Algerian Arabic, the local dialect, ensuring that respondents could engage with the questions in their native language. This translation process was critical for minimizing misunderstandings and ensuring the reliability of the data collected. During face-to-face interviews, trained interviewers provided verbal explanations and examples where needed, particularly for respondents with lower literacy levels, to ensure consistent understanding.

2.4. Data Analysis

To ensure a fair comparison, we applied random downsampling to balance the dataset by reducing the size of the majority group (males) to match the minority group (females). This approach prevents bias, ensuring that models or analyses do not favor the over-represented group. By providing an equal number of records for both genders, downsampling enables fair statistical comparisons and avoids skewed insights that could result from unbalanced data, which might otherwise lead to incorrect generalizations and misleading conclusions [21].

Prior to univariate modeling, Chi-square (χ^2) tests were used in an exploratory capacity to assess bivariate associations between key sociodemographic variables (e.g., gender, education, occupation, age, and site protection status) and perceptions of ecosystem services (ESSs), including provisioning, regulating, and cultural dimensions [22]. Given the number of comparisons conducted across survey items, we accounted for the increased risk of type I errors by applying both Bonferroni and False Discovery Rate (FDR) corrections. Whilst some associations remained statistically significant after adjustment, others did not persist under stricter thresholds. Chi-square analysis was therefore used to guide the specification of the subsequent ordered logistic regression models, which provided more robust estimates by incorporating covariates simultaneously and addressing potential confounding effects.

Following the identification of significant associations, regressions were employed to evaluate the strength and direction of these relationships. Ordered logistic regressions are appropriate for analyzing ordinal response variables, such as Likert scale survey responses [23]. To facilitate the interpretation of regression outputs, variables were encoded as follows: Binary variables were coded as follows: gender (0 = male, 1 = female), site protection status (0 = unprotected, 1 = protected), and age (0 = 20–60 years, 1 = over 60 years). Education was treated as an ordinal variable ranging from 1 (no formal education) to 5 (university level). Occupation was encoded categorically to capture variation across employment sectors (e.g., unemployed, farmer, employee). These encodings enable unambiguous interpretation of regression coefficients, where positive β values indicate increased odds of reporting stronger perceptions.

The analysis was conducted using R (version 4.3.1) [24]. The `polr` function from the MASS package [25] was used to fit the logistic regressions, providing robust estimates of the relationships between predictors and ordinal outcomes.

3. Results

As described in the Methods Section, downsampling reduced the sample from 597 to 552 to balance gender (276 males, 276 females). This adjustment may have affected the proportional distribution of other variables, such as occupation (e.g., farmers: 6.5%, $n = 36$) and age (e.g., >60 years: 15.2%, $n = 84$) (Table 1).

Table 1. The demographic characteristics of the sample ($n = 552$) were analyzed after downsampling to balance gender (50% male, 50% female). The table below summarizes the key variables of age, gender, education, occupation, and residence status.

Characteristic	Category	<i>n</i>	%
Gender	Male	276	50.0%
	Female	276	50.0%
Age	20–60 years	468	84.8%
	>60 years	84	15.2%
Education	Without formal education	92	16.7%
	Elementary school	108	19.6%
	Middle school	104	18.8%
	High school	162	29.3%
	University level	86	15.6%
Occupation	Unemployed	184	33.3%
	Employee	208	37.7%
	Farmer	36	6.5%
	Retired	24	4.3%
	Student	16	2.9%
	Others	84	15.2%
Residence Status	Protected	444	80.4%
	Unprotected	108	19.6%

3.1. Provisioning Services

Chi-square tests were conducted to examine the influence of gender and education on respondents' perceptions of provisioning ecosystem services (Q1–5) (Table 2). The analysis indicated that gender was not significantly associated with any of the provisioning service indicators after adjusting for multiple comparisons. While the raw p -value for perceived changes in service availability (Q2) was marginally significant ($\chi^2 = 12.73$, $p = 0.026$), this did not hold after correction, suggesting a potential but non-robust gender effect.

Table 2. Chi-Squared analysis of gender and education effects on provisioning services indicators.

Question	Gender χ^2 (p -Value)	Education χ^2 (p -Value)
Q1—Usage Frequency	7.86 (0.16)	80.71 (<0.001)
Q2—Perception of Changes	12.73 (0.026)	46.13 (0.03)
Q3—Importance to Well-Being	9.35 (0.15)	60.29 (0.006)
Q4—Policy Adequacy	2.67 (0.75)	48.29 (0.018)
Q5—Management Challenges	34.79 (0.05)	194.32 (0.001)

In contrast, education showed a stronger and more consistent relationship across multiple dimensions. Statistically significant associations were observed for all five indicators, including usage frequency ($\chi^2 = 80.71, p < 0.001$), perceived changes ($\chi^2 = 46.13, p = 0.030$), importance to well-being ($\chi^2 = 60.29, p = 0.006$), policy adequacy ($\chi^2 = 48.29, p = 0.018$), and identification of management challenges ($\chi^2 = 194.32, p = 0.001$). These findings suggest that educational attainment significantly shapes both the perception and engagement with provisioning services.

Univariate analysis using logistic regression revealed that none of the demographic variables—including gender, education, age, occupation, or site status—had a statistically significant effect across the provisioning service response variables. For instance, in Question 3 (Perceived Importance of Provisioning Services), the model yielded the following small and non-significant coefficients: gender ($\beta = 0.0573, p = 0.76$), education ($\beta = -0.0408, p = 0.68$), age ($\beta = -0.0070, p = 0.89$), occupation ($\beta = -0.1248, p = 0.33$), and site status ($\beta = 0.0911, p = 0.42$). Similar non-significant patterns were observed in the other provisioning service questions (Question 1–Question 5), reinforcing the interpretation that demographic characteristics exert limited influence on perceptions of provisioning services once other variables are controlled.

Overall, the results indicate that while gender and education significantly shape specific perceptions of provisioning services in bivariate analysis, these effects are not uniformly robust when controlling for other variables in univariate modeling.

3.2. Regulating Services

Chi-square tests were used to explore the effects of gender and education on perceptions of regulating ecosystem services (Q6–Q10) (Table 3). The results showed that gender was significantly associated with perceptions of environmental change (Q7: $\chi^2 = 16.36, p = 0.002$), although this association did not remain significant after applying corrections for multiple comparisons. No other gender-related associations reached statistical significance at the bivariate level.

Table 3. Chi-squared analysis of gender and education effects on regulating services indicators.

Question	Gender χ^2 (<i>p</i> -Value)	Education χ^2 (<i>p</i> -Value)
Q6—Concern Level	1.91 (0.75)	46.44 (0.003)
Q7—Perception of Changes	16.36 (0.002)	26.52 (0.32)
Q8—Knowledge of Benefits	6.42 (0.16)	19.28 (0.73)
Q9—Management Challenges	25.92 (0.16)	153.00 (0.02)
Q10—Policy Adequacy	1.46 (0.68)	14.97 (0.66)

In contrast, level of education demonstrated a more robust influence. Significant associations were found for concern about regulating service loss (Q6: $\chi^2 = 46.44, p = 0.003$) and identification of management challenges (Q9: $\chi^2 = 153.00, p = 0.020$), suggesting that individuals with higher educational attainment were more likely to recognize both the importance and governance-related barriers of regulating services. Education was not significantly associated with perceived environmental change (Q7), knowledge of benefits (Q8), or perceptions of policy adequacy (Q10).

These findings indicate that while gender effects are limited in the bivariate analysis, education plays a consistent role in shaping concerns about ecosystem functionality and management. The absence of significant differences in Q10 (Policy Adequacy) across all demographic groups ($p > 0.10$) suggests a shared skepticism regarding institutional responses to environmental management challenges.

Ordered logistic regression models revealed that several demographic variables significantly influenced perceptions of regulating services. In Question 6 (Level of Concern), both gender and site protection status were significant predictors: women expressed higher concern than men ($\beta = -0.6595, p = 0.005$) and respondents from protected areas were more likely to report elevated concern levels ($\beta = 0.8110, p = 0.023$).

For Question 7 (Perceived Environmental Change), gender ($\beta = -0.5418, p = 0.019$) and occupation ($\beta = 0.0837, p = 0.037$) were significant, suggesting that women and individuals in certain occupational groups (e.g., agriculture or fisheries) were more attuned to observed shifts in regulating services.

In Question 8 (Knowledge of Benefits), gender was the only significant variable, with women demonstrating greater awareness of the benefits of regulating services ($\beta = 0.3753, p = 0.030$).

Conversely, for Questions 9 (Perceived Management Challenges) and 10 (Policy Adequacy) none of the demographic predictors—including education, gender, occupation, or site status—were statistically significant (all $p > 0.10$), indicating a general consensus across groups regarding structural and policy-related issues affecting regulating services.

Overall, gender, education, occupation, and site protection status significantly shape perceptions of regulating ecosystem services—particularly in terms of environmental concern, awareness of ecological benefits, and recognition of environmental changes. These differences reflect the varying roles and experiences of demographic groups in interacting with natural systems. In contrast, perceptions of governance-related challenges and policy adequacy are more uniformly distributed across population segments, suggesting a broadly shared view of institutional shortcomings in managing regulating services.

3.3. Cultural Services

Chi-square analyses were conducted to assess associations between gender, education, and perceptions of cultural ecosystem services (Q11–Q17) (Table 4). Results indicated that gender was significantly associated with cultural engagement (Q11: $\chi^2 = 4.22, p = 0.030$), although this relationship did not remain significant after correction for multiple comparisons. No other gender-based associations reached statistical significance in the bivariate analysis. In contrast, education showed more consistent influence. Statistically significant associations were found for cultural engagement (Q11: $\chi^2 = 16.61, p = 0.010$), perceived importance of cultural services (Q12: $\chi^2 = 21.37, p = 0.040$), and participation in traditional ceremonies (Q14: $\chi^2 = 30.84, p = 0.002$). These results suggest that educational background is more strongly linked to variation in cultural perceptions than gender.

Table 4. Chi-squared analysis of gender and education effects on cultural services indicators.

Question	Gender χ^2 (<i>p</i> -Value)	Education χ^2 (<i>p</i> -Value)
Q11—Cultural Engagement	4.22 (0.03)	16.61 (0.01)
Q12—Perceived Importance	1.18 (0.55)	21.37 (0.04)
Q13—Learning About Significance	6.19 (0.10)	27.65 (0.06)
Q14—Traditional Ceremonies	0.05 (0.97)	30.84 (0.002)
Q15—Educational Integration	0.08 (0.76)	9.41 (0.15)
Q16—Perceived Impact of Loss	4.71 (0.19)	17.99 (0.12)
Q17—Preferred Promotion Strategies	8.22 (0.14)	26.31 (0.01)

3.4. Sociodemographic Associations

Chi-square analysis of the dataset is provided in Table 5, and it revealed no significant relationship between age and gender ($p = 0.75$). In contrast, age was strongly associated with education ($p < 0.0001$), with younger respondents (20–60 years) more likely to have higher education (e.g., high school or university) than those over 60 years of age. Men showed higher university-level education than women (18.1% vs. 13.0%, $p = 0.0003$). Additionally, significant differences in education levels were observed between men and women ($p = 0.0003$). Finally, occupation type was significantly linked to site status (protected vs. non-protected) ($p < 0.0001$).

Table 5. Adjusted Chi-square p -values using Bonferroni and FDR Corrections. Summary of raw and corrected p -values from Chi-square tests for gender and education across provisioning, regulating, and cultural ecosystem service indicators. Results show which associations remain statistically significant after applying Bonferroni and False Discovery Rate (FDR) corrections.

Test Category	Survey Question	Raw p -Value	Bonferroni Adj.	Bonferroni Reject	FDR Adj.	FDR Reject
Provisioning (gender)	Q1	0.16	1.0	False	0.2267	False
Provisioning (gender)	Q2	0.026	0.884	False	0.0785	False
Provisioning (gender)	Q3	0.15	1.0	False	0.2267	False
Provisioning (gender)	Q4	0.75	1.0	False	0.783	False
Provisioning (gender)	Q5	0.05	1.0	False	0.1133	False
Provisioning (education)	Q1	0.001	0.034	True	0.017	True
Provisioning (education)	Q2	0.03	1.0	False	0.0785	False
Provisioning (education)	Q3	0.006	0.204	False	0.034	True
Provisioning (education)	Q4	0.018	0.612	False	0.068	False
Provisioning (education)	Q5	0.001	0.034	True	0.017	True
Regulating (gender)	Q6	0.75	1.0	False	0.783	False
Regulating (gender)	Q7	0.002	0.068	False	0.017	True
Regulating (gender)	Q8	0.16	1.0	False	0.2267	False
Regulating (gender)	Q9	0.16	1.0	False	0.2267	False
Regulating (gender)	Q10	0.68	1.0	False	0.783	False
Regulating (education)	Q6	0.003	0.102	False	0.0204	True
Regulating (education)	Q7	0.32	1.0	False	0.4185	False
Regulating (education)	Q8	0.73	1.0	False	0.783	False
Regulating (education)	Q9	0.02	0.68	False	0.068	False
Regulating (education)	Q10	0.66	1.0	False	0.783	False
Cultural (gender)	Q11	0.03	1.0	False	0.0785	False
Cultural (gender)	Q12	0.55	1.0	False	0.6926	False
Cultural (gender)	Q13	0.1	1.0	False	0.2	False
Cultural (gender)	Q14	0.97	1.0	False	0.97	False
Cultural (gender)	Q15	0.76	1.0	False	0.783	False

Table 5. Cont.

Test Category	Survey Question	Raw <i>p</i> -Value	Bonferroni Adj.	Bonferroni Reject	FDR Adj.	FDR Reject
Cultural (gender)	Q16	0.19	1.0	False	0.2584	False
Cultural (gender)	Q17	0.14	1.0	False	0.2267	False
Cultural (education)	Q11	0.01	0.34	False	0.0425	True
Cultural (education)	Q12	0.04	1.0	False	0.0971	False
Cultural (education)	Q13	0.06	1.0	False	0.1275	False
Cultural (education)	Q14	0.002	0.068	False	0.017	True
Cultural (education)	Q15	0.15	1.0	False	0.2267	False
Cultural (education)	Q16	0.12	1.0	False	0.2267	False
Cultural (education)	Q17	0.01	0.34	False	0.0425	True

Findings from the ordered logistic regression models further clarified these relationships. Higher levels of education were negatively associated with cultural participation (Q11: $\beta = -0.3671$, $p = 0.042$), indicating reduced engagement in biodiversity-related cultural activities among university-educated respondents. However, education had a positive effect on learning about cultural significance (Q13: $\beta = 0.1848$, $p = 0.022$), suggesting greater conceptual awareness despite lower practical involvement.

Gender was a significant predictor of perceived importance (Q12: $\beta = -0.6188$, $p = 0.004$), with women assigning higher value to cultural services. Proximity to protected areas also shaped perceptions, significantly influencing the perceived importance of cultural services (Q12: $\beta = 0.7765$, $p = 0.011$), participation in traditional ceremonies (Q14: $\beta = 1.5594$, $p < 0.001$), and support for educational integration (Q15: $\beta = 5.4471$, $p = 0.004$).

Occupation was negatively associated with participation in ceremonies (Q14: $\beta = -0.1870$, $p < 0.001$) and significantly influenced preferred promotion strategies (Q17: $\beta = -0.0814$, $p = 0.006$). Perceived cultural loss (Q16) was not significantly associated with any demographic variable, though age approached marginal significance ($\beta = 0.6508$, $p = 0.092$).

Together, these results suggest that education, gender, occupation, and site status meaningfully influence how cultural ecosystem services are valued and experienced. Educational attainment appears to increase abstract appreciation of cultural biodiversity but is associated with reduced engagement in traditional practices—underscoring a shift away from experiential knowledge. In contrast, women and residents of protected areas demonstrated stronger cultural attachments, highlighting the importance of integrating local traditions into conservation strategies.

A full comparison of bivariate and univariate results across all 17 questions is provided in Supplementary Materials File S4.

4. Discussion

4.1. Sociodemographic Influences on Ecosystem Service Perceptions

The findings from this study illuminate the critical role of gender, education, occupation, and spatial context in influencing how communities perceive and engage with ecosystem services (ESs) in Numidia. Notably, women demonstrated heightened sensitivity to environmental degradation and deeper involvement in cultural ecosystem services. This is consistent with existing research, which emphasizes women's informal yet influential stewardship in biodiversity-rich contexts [26,27]. Despite this engagement, systemic constraints and legal, cultural, and economic barriers continue to hinder their participation in formal environmental governance structures [28,29].

Education emerged as a key determinant in shaping perceptions of biodiversity's significance. Individuals with higher educational attainment showed greater recognition of ecological and cultural ESs, aligning with broader global patterns [12,13]. However, this awareness often coincides with reduced participation in traditional ecological practices, indicating a tension between formal environmental education and the continuity of traditional knowledge systems.

In addition, professional background and residency in protected versus non-protected sites further influenced how ecosystem services were valued. Those engaged in resource-dependent livelihoods such as farming and fishing displayed stronger connections to provisioning and regulating services, likely due to their daily reliance on these functions. Similarly, residents of protected areas demonstrated a more profound appreciation for cultural services, highlighting how geographic proximity to natural ecosystems can foster ecological awareness and emotional affinity [30].

4.2. Provisioning Services: The Role of Education over Gender

Education plays a significant role in shaping how people view provisioning services, such as food and water, in Numidia's wetlands. Those with formal education tend to have a deeper understanding of the importance of these resources and are better able to identify challenges in managing them sustainably. However, these individuals often engage less in traditional practices like farming or fishing that directly rely on these services. While education enhances conceptual understanding of ecosystem functions, it is also associated with lower participation in traditional practices, likely influenced by shifts in livelihood, urban migration, or reduced dependence on local resources. To address this, educational programs should incorporate practical, place-based experiences that encourage direct interaction with natural systems, fostering a stronger connection to local environments [31,32].

These insights reinforce the role of provisioning services in supporting not only subsistence but also broader dimensions of well-being across demographic groups.

Women, on the other hand, often express greater concern about declines in provisioning services, likely due to their daily responsibilities which frequently involve managing household resources like water or food. This sensitivity to environmental changes reflects their lived experiences and close reliance on local ecosystems. However, these observations should be considered carefully as the differences between men and women are not always clear-cut. Despite their awareness, women face significant barriers—such as restrictive policies and societal norms—that limit their ability to participate in formal conservation efforts or influence resource management decisions [14,33]. Addressing these challenges requires creating opportunities for women to play a more active role in environmental governance, ensuring their insights and experiences shape sustainable practices.

4.3. Cultural Services: The Dual Influence of Gender and Education

Cultural services, such as biodiversity-related traditions and practices, are shaped more consistently by education than by gender in Numidia's wetland communities. In rural areas, women often act as informal keepers of cultural heritage, passing down ecological knowledge through oral traditions, ceremonies, and daily activities [34,35]. While women tend to show stronger engagement with these cultural practices, this pattern did not emerge as statistically significant in our analysis and should therefore be interpreted with caution. In contrast, education has a more consistent impact. Rapid modernization and greater access to formal schooling have led to a decline in participation in traditional practices, especially among younger and more educated individuals [36,37]. At the same time, education can serve as a tool to reframe cultural ecosystem services in modern contexts.

For instance, educational programs can use non-native species, often seen as ecological challenges, to spark environmental awareness among urban youth [38].

While formal education deepens understanding of cultural biodiversity's value, it can sometimes overshadow community-based knowledge passed down through lived experience [39–41]. Additionally, people's occupations and proximity to protected areas play a role in cultural engagement. Those working in resource-based jobs, like farming or fishing, and residents living near biodiverse wetlands tend to have stronger ties to traditional values.

Although our survey did not reveal a statistically significant gender effect in cultural engagement, women's potential role in preserving traditional ecological knowledge (TEK) remains evident through sociocultural observations. In other Algerian communities, Tuareg women, for example, transmit environmental knowledge through poetry and oral traditions [42]. These parallels highlight the potential for TEK to inform conservation, although such knowledge faces risks from modernization and the erosion of intergenerational transmission. To authentically capture Numidia's TEK, future research should involve community members in qualitative studies, such as interviews or focus groups, to document practices like wetland-related rituals or resource management techniques. Such efforts would ensure that local voices shape conservation strategies, fostering inclusive stewardship [2,43].

4.4. Integrating Gender and Traditional Knowledge into Conservation Governance of Regulating and Cultural Services

Women in Numidia's wetland communities play a multifaceted role in sustaining both regulating and cultural ecosystem services, a role rooted in their daily responsibilities and intergenerational ecological knowledge. Their pronounced concern over the degradation of services such as climate regulation, flood control, and soil stability underscores a lived dependence on these functions, particularly in managing household resources like water, fuel, and food [26,44]. This everyday interaction with natural systems positions women as key, although often informal, stewards of ecosystem resilience.

This study confirms gender as a statistically significant predictor of concern and benefit awareness regarding regulating services, reinforcing earlier findings that women's lived experiences cultivate acute environmental sensitivity [14,28].

However, despite this awareness, women remain under-represented in formal conservation governance due to enduring legal and cultural constraints. Algeria's Family Code (1984), along with broader patriarchal norms, continues to restrict women's mobility and influence in public decision-making [29,45,46]. As a result, a gap persists between informal stewardship and formal environmental authority, limiting the integration of women's perspectives in policy and planning.

At the same time, cultural ecosystem services—such as biodiversity-related traditions, ceremonies, and storytelling—are shaped more strongly by education than by gender. While women often serve as informal custodians of traditional ecological knowledge (TEK), preserving ecological wisdom through oral transmission and ritual [34,42], our analysis found that higher levels of formal education correlated with decreased participation in such cultural practices. This aligns with broader literature suggesting that modernization and increased schooling can weaken community-based knowledge systems, especially among the young [31,36,37].

Nonetheless, education also contributes positively by enhancing the conceptual understanding of the ecological and cultural value of biodiversity [12,13]. This dual effect suggests a need for educational programs that integrate local knowledge and practices to avoid marginalizing TEK while promoting ecological literacy [39,41].

Geographic proximity to protected areas also influences perceptions, as residents near conservation zones reported stronger appreciation for both regulating and cultural services, which is consistent with studies highlighting the place-based nature of ecological attachment and awareness [30,47]. This finding supports the integration of TEK and community-led engagement within conservation efforts.

To bridge existing divides between institutional governance and local ecological knowledge, participatory approaches are essential. Documenting TEK through oral histories, community interviews, or participatory mapping can help ensure that traditional practices—particularly those upheld by women—are recognized and integrated into environmental strategies [2,43]. Such approaches promote inclusive conservation, grounded in both scientific and cultural understandings of ecosystem sustainability.

4.5. The Role of Protected Areas in Shaping Perceptions

Findings from this research underscore the positive influence of protected areas in cultivating ecological awareness and cultural attachment to nature. Residents in these zones demonstrated stronger concern for biodiversity loss and greater participation in cultural practices. These observations support prior arguments that conservation proximity can foster environmental values and stewardship [46].

Such insights reinforce the value of community-based conservation initiatives that recognize and incorporate informal, localized knowledge systems. Formalizing these roles within conservation governance can improve both ecological outcomes and social equity [47,48]. To translate these findings into actionable conservation policy in Algeria, several steps are recommended. First, gender-responsive planning should be formally embedded into wetland management frameworks, particularly by involving women in decision-making councils at protected sites. This could be achieved through quotas, training programs, or local stewardship roles. Second, environmental education initiatives should be tailored to different education levels and designed to reconnect formal knowledge with traditional ecological practices. Partnering with schools, mosques, and civil society groups can extend reach and cultural resonance. Third, policymakers should prioritize participatory governance models in protected wetlands, ensuring that both educated and traditionally knowledgeable community members, especially those in resource-dependent occupations, are consulted during management planning. These approaches align with Algeria's national biodiversity strategy and international commitments under the Ramsar Convention and SDGs, offering a pathway to more inclusive, effective, and culturally grounded conservation.

5. Conclusions

These findings emphasize the need for localized, gender-responsive conservation strategies that recognize the value of both formal education and traditional ecological knowledge in shaping environmental attitudes.

Importantly, the conclusions of this study align with global sustainability priorities, particularly Sustainable Development Goal (SDG) 5 (Gender Equality) and SDG 15 (Life on Land). Persistent gender disparities in environmental leadership and access to resources hinder inclusive conservation. Overcoming these challenges requires systemic reforms in education, mobility, and legal empowerment for women [49]. Advancing SDG 15 similarly calls for integrating ecological science with culturally grounded conservation practices.

As biodiversity loss accelerates, the success of conservation efforts in Numidia and similar regions will depend on inclusive, community-based governance frameworks that elevate the voices of women and local, resource-dependent groups. Embedding their

knowledge and lived experiences into policy can set a precedent for adaptive conservation that supports both social equity and ecological resilience [50].

This study highlights the critical influence of gender, education, occupation, and residence in protected areas on perceptions of ecosystem services in Numidia's wetlands. Women demonstrated greater sensitivity to cultural and regulating services, reflecting their role as informal stewards of ecological and cultural knowledge, yet systemic barriers limit their formal participation in conservation governance. Higher education levels were associated with increased ecological awareness but reduced engagement in traditional practices, underscoring a tension between formal and traditional knowledge systems. Residents of protected areas and those in resource-dependent occupations showed stronger connections to ecosystem services, emphasizing the importance of place-based conservation strategies. The findings reflect and support the goals emphasized in key global sustainability initiatives, such as the Millennium Ecosystem Assessment [1] and the IPBES [2], and support the need for inclusive, gender-responsive, and community-driven conservation policies.

Future research should focus on qualitative approaches, such as participatory mapping and in-depth interviews, to further document traditional ecological knowledge (TEK), particularly among women and resource-dependent communities. Additionally, longitudinal studies could explore how educational interventions and policy reforms influence perceptions over time, fostering adaptive management strategies that integrate local knowledge with scientific approaches. By centering local voices and addressing structural inequities, conservation efforts in Numidia can serve as a model for equitable and resilient environmental governance in biodiversity-rich regions.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/land14071454/s1>, File S1: Provisioning Services Questions; File S2: Regulating Services Questions; File S3: Cultural Services Questions; File S4: Full Comparison of Bivariate and Multivariate Results for Ecosystem Service Questions.

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