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Barriers and drivers of ammonium nitrate fertilization adoption for barley in Tunisia's dryland systems: do farmers' perceptions matter?

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Abstract

Water scarcity and climate change threaten agricultural productivity in North Africa, particularly Tunisia. This study examines how smallholder farmers' perceptions and farm-related conditions influence current use and future intention to use ammonium nitrate fertilizer. Survey data from 671 farmers were analysed using logistic regression. While 45.2% of respondents currently use ammonium nitrate, 66.3% intend to use it in the future. Current use is associated with access, financial capacity, perceived skills, information support, and exposure to shocks. Reporting bad and very bad access is associated with 61.9% and 71.6% lower odds of current ammonium nitrate use, respectively. Higher perceived skills and ability to pay increase the odds of current use by 37.3% and 31.5%, respectively. Information obtained through NGOs or government services is associated with approximately 5.5 times higher odds of current use. Hail exposure reduces current use, whereas wind shocks increase it. Future intention is shaped more strongly by prior experience, perceived benefits, constraints, and economic shocks. Each additional year of ammonium nitrate use increases the odds of future intention by 16.2%. Expected higher yields (OR = 17.05), drought resistance (OR = 16.74), and negotiability (OR = 26.80) significantly increase intention. Conversely, limited land (OR = 0.071), limited information (OR = 0.087), and lack of labour (OR = 0.332) significantly reduce future intention. Livestock loss, input-price increases, higher household consumption costs, and broader economic shocks also reduce farmers' intentions to use ammonium nitrate. Policies should strengthen extension, improve affordability and access, and link fertilizer management with climate-resilient soil and water practices.

Keywords: Adoption, Ammonium nitrate, Logit model, Perception, Smallholder farmers, Sustainability.

1. Introduction

Water scarcity affects over 40% of the global population today, a figure projected to rise by 2050 due to global warming (Roshan and Kumar, 2020). This scarcity may reduce worldwide

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agricultural productivity by 9–21% by 2050 (Savari et al., 2021), with droughts, groundwater depletion, declining yields, and rising food prices increasingly affecting many regions (Mfitumukiza et al., 2020). These challenges are particularly acute in the Middle East–North Africa region, where freshwater reserves are among the lowest globally. Tunisia is especially vulnerable because its arid and semi-arid climate, declining dam recharge, and rainfall variability constrain agricultural production and the sustainability of dryland systems (Souissi et al., 2019; Sherif et al., 2023). Water scarcity reduces crop growth, biomass production, grain filling, and yield, with adverse consequences for farm income and food security.In Tunisian dryland agriculture, adaptation requires improved management of available resources, including fertilizer inputs. Nitrogen fertilization can improve cereal yield and water-use efficiency when applied under suitable agronomic conditions (Cossani et al., 2011). However, its effectiveness and sustainability depend on farmers' capacity to access inputs, assess benefits and risks, and apply fertilizer appropriately. Although the agronomic and economic effects of nitrogen fertilization have been widely examined, , less is known about how farmers' perceptions influence its adoption, especially in water-scarce Tunisian dryland systems. Previous studies have focused on economic and technical determinants of fertilizer adoption (Monjardino et al., 2015; Oliveira Silva et al., 2020), but perception-based barriers and drivers remain underexplored. Understanding farmers' decision-making on ammonium nitrate use is essential to promoting balanced and sustainable strategies. Integrating prudent fertilizer application offers a more resilient approach to drought and climate change, supporting farm efficiency, productivity, and long-term sustainability. This study addresses this gap by investigating how farmers' perceptions shape ammonium nitrate adoption for barley in Tunisia's dryland systems, providing evidence to inform policy and extension programs for sustainable intensification.

2. Background

Dryland agriculture involves rainfed crops under semi-arid or arid conditions with scarce, unpredictable rainfall, making production highly sensitive to climate variability (Savin et al., 2022). Since the 1990s, nitrogen (N) fertilization has become common in rainfed grain systems in regions less water-limited than the Mediterranean and in irrigated agriculture, yet farmers in the southern Mediterranean Basin remain reluctant to fertilize rainfed crops, perceiving ammonium nitrate as risky and expecting weak yield responses under dryland conditions (Monjardino et al., 2015; Oliveira Silva et al., 2020). At the same time, agronomic evidence shows that properly adapted N fertilization can substantially reduce yield gaps in many rainfed areas (Cossani and Sadras, 2018; Sadras et al., 2019), revealing a discrepancy between experimental results and on-farm decisions. This tension is particularly visible for barley. Farmers are more hesitant to fertilize barley than wheat, assuming barley is suited to marginal soils and responds less consistently to fertilization (Cossani et al., 2007; Savin et al., 2022). However, Mediterranean trials indicate that barley can respond well to N inputs, including ammonium nitrate, when rates and timing are adapted to local conditions (Cossani et al., 2009, 2011; Savin et al., 2022). The contrast between these findings and farmers' reluctance suggests that perceptions, rather than agronomic potential alone, are central to understanding adoption behaviour.

Recent research emphasizes the need to balance productivity and environmental impact by optimizing N rates and improving fertilizer use efficiency without lowering yields (Mandrini et al., 2022; Pan et al., 2022; Yokamo et al., 2023). In Tunisia, advancing management practices and innovation is critical to sustaining agriculture's economic role under price volatility and climate stress (Dhehibi et al., 2023). Strategic options that stabilize farmer incomes and promote cost-effective production are essential, especially for crops like barley, a staple in northern and central semi-arid zones that supports both food security and livestock grazing (Medimagh et al., 2012; Sadreddine, 2016; Hammami et al., 2020).

This study focuses on ammonium nitrate because it is a widely used nitrogen source in Mediterranean cereal systems and offers relatively high nitrogen use and water-use efficiency compared with several alternative fertilizers, while simultaneously raising specific concerns about nitrate leaching and farmers' perception of input-related risk (Begho et al., 2022; Dai et al., 2023). However, agronomic trials and adoption studies address different dimensions of the fertilizer question. Experimental evidence generally identifies the biophysical conditions under which nitrogen improves yields, whereas adoption research commonly emphasizes observable household, farm, and market characteristics, such as landholding, credit, prices, and extension access. These approaches are complementary, but neither alone sufficiently explains why farmers may avoid an input with demonstrated agronomic potential when rainfall is uncertain, liquidity is constrained, or expected returns are perceived as unreliable (Olum et al., 2020). Moreover, much of the available evidence treats fertilizer adoption as a single, binary decision. This can obscure the distinction between actual use, which reflects farmers' immediate resources and access conditions, and future intention, which may depend more strongly on expectations, perceived benefits, and anticipated risks. This distinction is particularly relevant for ammonium nitrate in dryland barley systems, where the profitability of application is contingent on highly variable rainfall and where concerns about fertilizer costs and environmental effects may shape farmers' choices.

Despite extensive work on fertilizer response and adoption, few studies explicitly examine how farmers' perceptions of ammonium nitrate, mainly about its agronomic benefits, economic risks, and environmental impacts shape adoption decisions in dryland barley systems. The present study therefore moves beyond assessing whether farmers adopt ammonium nitrate by examining how perception-based factors interact with socio-economic, climatic, infrastructural, and institutional conditions. It investigates the factors influencing ammonium nitrate fertilization adoption for barley in Tunisia, with a specific focus on perception-driven behaviour. It asks: (1) What are farmers' knowledge, experiences, and perceptions regarding ammonium nitrate fertilizer? (2) Which perception dimensions are associated with current use and with farmers' propensity to adopt ammonium nitrate in the future? and (3) Which socio-economic, environmental, infrastructural, and human factors are associated with current and future ammonium nitrate use and adoption propensity? By separately modelling current use and future intention in a large sample of Tunisian smallholders, the study provides evidence on the gap between agronomic potential and farmer decision-making under water scarcity. The findings offer insights for policy and extension strategies aimed at sustainable intensification in water-scarce regions.

3. Theorical framework

Agricultural decision-making is complex, shaped by multiple factors, a multifaceted environment, past experiences, and improvement opportunities. Many studies adopt normative theory, focusing on economic factors and profit maximization (Gould, 1963). Naturalistic theory offers a descriptive perspective: decision-makers assess situations, classify problems using knowledge and experience, and choose the best action (Klein et al., 1993). Fishbein and Ajzen (1975) emphasize attitudes, subjective norms, intentions, and behaviours, linking beliefs to behavioural intentions and actions (Martin-Clouaire, 2017). This framework is known as the Theory of Planned Behavior (TPB). Waldman et al. (2020) note agricultural decision-making was traditionally dominated by economists using mathematical models assuming perfect rationality and information. Behavioral economics challenges this, highlighting real-world processes using heuristics or cognitive shortcuts (Dijk et al., 2022). Decision-making is bounded by limited information, cognitive constraints, and time pressures (Bokati et al., 2020).

Understanding these decision processes is especially important in the context of climate change and agricultural adaptation. Meijer et al. (2015) stress that adoption decisions are complex and shaped by the interaction between farmer characteristics, the external environment, innovation attributes, intrinsic factors, and communication and extension. Their framework provides a useful basis for understanding agricultural decision-making and adoption, as illustrated in Figure 1.

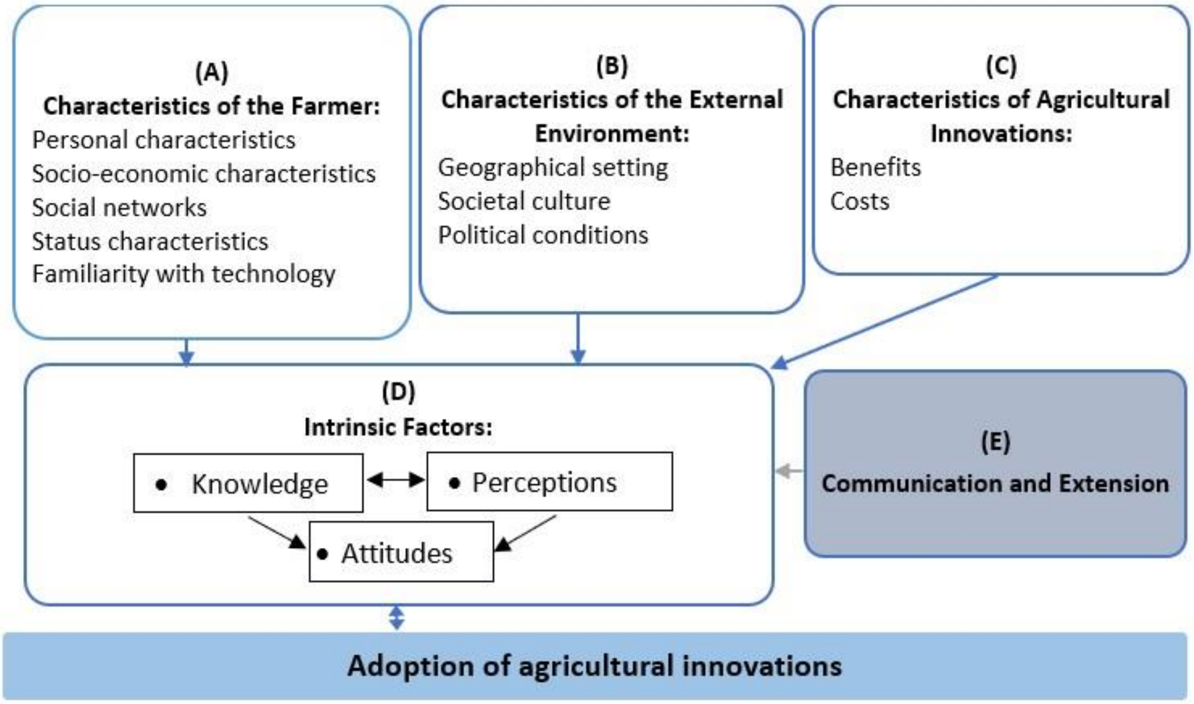

Figure 1. Conceptual framework showing the linkages and interaction between extrinsic (A–C) and intrinsic (D) variables, and the influence of the intervening variable (E) in the decision-making process of adoption of agricultural innovations (Meijer et al., 2015).

In line with this framework, the present study considers (A) characteristics of the farmer, including personal and socio-economic characteristics, social networks, status characteristics, and familiarity with technology; (B) characteristics of the external environment, including geographical setting, societal culture, and political conditions; (C) characteristics of the agricultural innovation, including perceived benefits and costs; and (E) communication and extension. These elements influence (D) intrinsic factors, namely knowledge, perceptions, and attitudes, which in turn affect adoption of agricultural innovations. In practice, our questionnaire captures intrinsic factors in the form of knowledge and perceptions of ammonium nitrate, while items such as ability to pay and dependence on the environment are treated as perceived behavioural control/context; we do not include a separate attitude variable in the strict TPB sense.

This structure guided the selection and classification of the explanatory variables presented in Table 1.

Although the Theory of Planned Behavior and adoption frameworks are useful for identifying behavioural mechanisms, they should not be interpreted as implying that farmers' choices arise solely from individual attitudes or intentions. In dryland settings, farmers may perceive ammonium nitrate favourably but remain unable or unwilling to use it because of limited liquidity, weak input access, uncertain rainfall, land constraints, or anticipated output-price risks. Conversely, current use may reflect past experience, habitual practices, or temporary input availability rather than a stable positive intention. For this reason, the study does not treat perceptions as isolated psychological attributes; rather, it examines them together with environmental shocks, farm resources, market access, and communication support. This integrated approach enables a more context-sensitive interpretation of the divergence between current use and future adoption propensity.

The diffusion of innovations literature recognizes perceptions as important precursors of adoption decisions (Agarwal and Prasad, 1998). However, their effects may vary across farmers and contexts because perceived benefits and risks are mediated by resource availability, institutional support, and production conditions (Ajzen and Fishbein, 1980; Hermans et al., 2020). In this study, knowledge and perceptions of ammonium nitrate are treated as intrinsic factors, whereas information sources and extension support represent communication pathways. Perceived labour requirements, cost, access, availability, and yield performance are considered farmer-evaluated attributes of the innovation, reflecting how ammonium nitrate is assessed under actual production and market conditions.

4. Material and Methods

This research was conducted in the framework of the research project "Mind the Gap: Improving Dissemination Strategies to Increase Technology Adoption by Smallholders." [4]

Study area and data collection

The study was conducted in the Zaghouan and Kairouan governorates in Tunisia (Figure 2), which have semi-arid to arid climates, with annual rainfall ranging from 200 to 450 mm.

[4] https://icarda.org/research/projects/mind-gap-improving-dissemination-strategies-increase-technology-adoption#:~:text=Mind%20the%20Gap:%20Improving%20Dissemination%20Strategies%20to%20Increase%20Technology%20Adoption

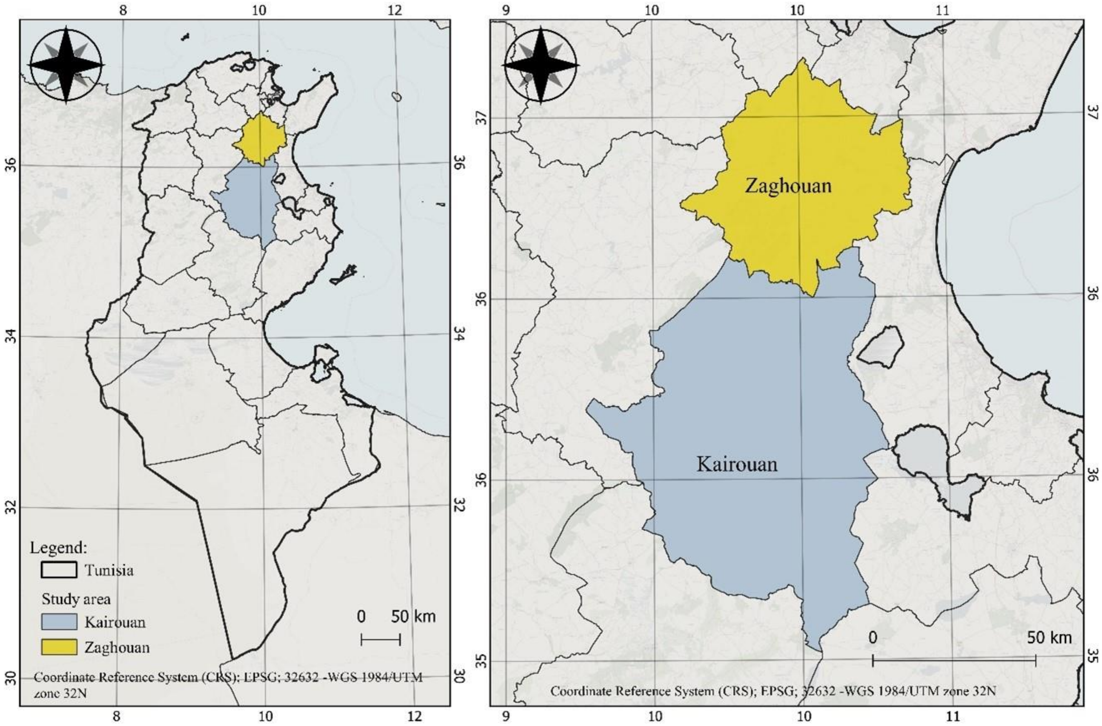

Figure 2. Map of Tunisia highlighting the locations of Kairouan and Zaghouan governorates.

A quantitative, cross-sectional study was conducted in 2018 within the Mind the Gap project, using stratified random sampling to survey 671 small-scale farmers (217 in Zaghouan and 454 in Kairouan) through face-to-face questionnaires comprising 17 modules on technology and agricultural practices adoption, with adult volunteers providing written informed consent.

Data analysis

A descriptive analysis was used to identify the main socio-economic characteristics of the selected farmers, characterize the users of ammonium nitrate, identify the main reasons for not using ammonium nitrate now and in the future, and identify the main source of information on ammonium nitrate use. Correlations and chi-square tests were used to identify the main intrinsic and extrinsic variables related to the use of ammonium nitrate for barley.

Logistic regression is a statistical approach for examining the relationship between one or more independent variables and a binary dependent variable, providing the probability of a favourable outcome based on specific predictors. It is particularly suited to studies with binary results, making it valuable for evaluating factors affecting the likelihood of an event occurring, such as technology or practice adoption in agriculture (Conteh et al., 2016; Chebil et al., 2024). In this research, logistic regression models were applied to identify factors influencing farmers' current and future adoption of ammonium nitrate fertilization in barley cultivation. The analysis considered two binary dependent variables (current and intended future use of ammonium nitrate) and three blocks of explanatory variables: extrinsic factors (demographics, land, location and road access, fertilization and input conditions, and recent weather and economic shocks recalled over the previous three years), intrinsic factors (knowledge and experience with ammonium nitrate, perceived behavioural control and benefits), and communication-related variables (information sources and extension support), providing a structured assessment of how external conditions, internal dispositions and information pathways shape adoption decisions (Table 1).

In this dryland barley system, mineral fertilization remains limited and ammonium nitrate is the main nitrogen source used by farmers in our sample, with very few reporting the use of alternative N fertilizers. Consequently, we did not include a separate control variable for other nitrogen sources, and we note that this is a contextual limitation of the present analysis. Prior to estimation, multicollinearity among the explanatory variables was assessed using the variance inflation factor (VIF).

The decision of a farmer to adopt ammonium nitrate fertilization is expressed as follows:

$$W = f(x, \epsilon) \quad (1)$$

where W represents the farmer's decision to adopt fertilization, x is the vector of explanatory variables for that decision, and ϵ is the error term. The logistic model is specified as:

$$log \frac{P(Y_i=1)}{(1-P(Y_i=1)} = \beta_0+\beta_1 X_{1i}+\beta_2 X_{2i}+\cdots+\beta_n X_{ni}+\varepsilon_i \quad (2)$$

Where $P(Y_i=1)$ is the probability of adoption; β_0 is the intercept, β_1, β_2, …, β_n are the coefficients of the explanatory variables, and; X_1, X_2, …, X_n are the independent variables; and ϵ represents the error term accounting for unexplained variability in the model.

Most explanatory variables are consistent with previous findings on factors shaping farmers' fertilizer use. Education enhances understanding of integrated soil fertility management, reducing over-fertilization risks (Zhou et al., 2010). Farm size, output, and fertilizer prices strongly influence use, with larger farms generally applying fertilizers more efficiently (Zhou et al., 2010; Bester et al., 2017; Dhehibi et al., 2023). Expected yield gains correlate positively with fertilizer intensity, while smaller landholders show lower awareness of sustainable practices (Farouque and Takeya, 2007). Exposure to communication and farming experience further shape perceptions and choices. Demographic variables such as gender, age, and household size exert limited effects (Blessing et al., 2010). Other influential factors include income, total yield, extension access, risk perception, and alternative input costs (Pandey and Diwan, 2018).

Table 1. Logit models – dependent and explanatory variables.

Variable description	Variable name	Type of measure	Modality
Dependent variables			
Current use of ammonium nitrate	Ammonium_nitrate_use	Dummy	1 = Yes, 0 = No
Intended future use of ammonium nitrate	Ammonium_nitrate_future_use	Dummy	1 = Yes, 0 = No
Intrinsic variables			
Perceptions and reasons for non-use			
Reasons for non-use	Ammonium_nitrate_non_use_reasons	Categorical	Low yield; Limited land; Limited information; Lack of labour
Perceived benefits			
Perceived benefits of ammonium nitrate	Ammonium_nitrate_benefits	Categorical	Saves money; Saves labor; Higher yields; Drought resistance
Knowledge			
Years of ammonium nitrate use	Years_using_ammonium_nitrate	Continuous	Years
Knowledge level on ammonium nitrate	Knowledge_level_ammonium_nitrate	Categorical	1 = Very low, 2 = Low, 3 = High, 4 = Very high
Required skills for use	Required_skills_ammonium_nitrate	Scale	1 = Not at all able, 10 = Fully able
Perceived behavioral control / context			
Ability to pay for ammonium nitrate	Ability_to_pay_ammonium_nitrate	Scale	1 = Not at all able, 10 = Fully able
Dependence on environment	Dependence_on_environment	Scale	0 = Not at all, 1 = To a small extent, 2 = To a large extent
Extrinsic variables			
Farmer characteristics			
Age of household head	Age	Continuous	Years
Gender of household head	Gender	Dummy	1 = Male, 0 = Female
Agricultural degree	Has_agricultural_degree	Dummy	1 = Yes, 0 = No
Farm ownership	Is_farm_owner	Dummy	1 = Yes, 0 = No
Total owned land	Total_owned_land_ha	Continuous	Hectares
Fertilization and access characteristics			
Yield comparison	Yield_comparison	Categorical	1 = Better, 2 = Worse, 3 = Indifferent
Perceived access to ammonium nitrate	Access_to_ammonium_nitrate	Categorical	1 = Very good, 2 = Good, 3 = Bad, 4 = Very bad
Perceived cost of ammonium nitrate	Cost_of_ammonium_nitrate	Categorical	1 = Very low, 2 = Low, 3 = High, 4 = Very high
Perceived labour requirement	Labour_requirement_ammonium_nitrate	Categorical	1 = Very low, 2 = Low, 3 = High, 4 = Very high
Perceived ability to obtain and use ammonium nitrate next season, given local availability and required inputs/resources	Ability_to_obtain_ammonium_nitrate	Scale	1 = Not at all able, 10 = Fully able
External environment			
Governorate	Governorate	Categorical	0 = Zaghouan, 1 = Kairouan
Distance to input market	Distance_to_input_market	Continuous	km
Shocks (last 3 years)			
Drought shock	Shock_drought	Dummy	1 = Yes, 0 = No
Temperature shock	Shock_temperature	Dummy	1 = Yes, 0 = No
Hail shock	Shock_hail	Dummy	1 = Yes, 0 = No
Wind shock	Shock_wind	Dummy	1 = Yes, 0 = No
Flood shock	Shock_flood	Dummy	1 = Yes, 0 = No
Input price increase	Shock_input_price_increase	Dummy	1 = Yes, 0 = No
Product price decrease	Shock_product_price_decrease	Dummy	1 = Yes, 0 = No
Food consumption cost increase	Shock_food_cost_increase	Dummy	1 = Yes, 0 = No
Worst shock experienced			
Worst shock: loss of harvest	Worst_shock_loss_harvest	Dummy	1 = Yes, 0 = No
Worst shock: loss of livestock	Worst_shock_loss_livestock	Dummy	1 = Yes, 0 = No
Worst shock: biological shock	Worst_shock_biological	Dummy	1 = Yes, 0 = No
Worst shock: input price increase	Worst_shock_input_price_increase	Dummy	1 = Yes, 0 = No
Worst shock: product price decrease	Worst_shock_product_price_decrease	Dummy	1 = Yes, 0 = No
Worst shock: food cost increase	Worst_shock_food_cost_increase	Dummy	1 = Yes, 0 = No
Worst shock: economic shock	Worst_shock_economic	Dummy	1 = Yes, 0 = No
Communication and extension variable			
Information source from research centres/NGOs/government	Information_source_ammonium_nitrate	Dummy	1 = Yes, 0 = No

5. Results and discussion

Farmers' socio-economic and demographic characteristics

The sample includes 671 farmers, mainly from Kairouan and Zaghouan. While 45.2% currently use ammonium nitrate, 66.3% plan to use it in the future. Women represent only 6.5% of the sample and only 5.96% of respondents hold an agricultural degree, indicating a generally low level of formal agricultural training in the sample (Table 2).

Table 2. Socio-economic and demographic characteristics of the farmers, ammonium nitrate fertilization use perception, and shocks variables (n = 671).

Variable description	Variable name	Number of observations	Frequency	Percentage
Gender	Gender	667		
Women			43	6.45
Men			624	93.55
Farm ownership	Is_farm_owner	671		
Yes			618	92.10
No			53	7.90
Agricultural degree	Has_agricultural_degree	671		
Yes			40	5.96
No			631	94.04
Current use of ammonium nitrate	Ammonium_nitrate_use	671		
Yes			303	45.16
No			368	54.84
Future use of ammonium nitrate	Ammonium_nitrate_future_use	671		
Yes			445	66.32
No			226	33.68
Governorate	Governorate	671		
Zaghouan			217	32.34
Kairouan			454	67.66
Perception variables				
Reasons for non-use	Ammonium_nitrate_non_use_reasons	368		
Low yield			19	5.16
Limited land			48	13.04
Limited information			77	20.92
Lack of labor			100	27.17
Perceived benefits	Ammonium_nitrate_benefits	640		
Saves money			2	0.31
Saves labor			4	0.62
Higher yields			555	86.72
Drought resistance			18	2.81
Knowledge level	Knowledge_level_ammonium_nitrate	671		
Very low			69	11.40
Low			128	21.16
High			270	44.63
Very high			138	22.81
Dependence on environment	Dependence_on_environment	671		
0			233	35.96
1			184	28.40
2			231	35.65
Access perception	Access_to_ammonium_nitrate	671		
Very good			73	11.79
Good			228	36.83
Bad			185	29.89
Very bad			133	21.49
Labor perception	Labour_requirement_ammonium_nitrate	671		
Very low			108	18.37
Low			92	15.65
High			274	46.60
Very high			114	19.39
Drought shock	Shock_drought	671		
Yes			661	98.51

No			10	1.49
Temperature shock	Shock_temperature	671		
Yes			457	68.11
No			214	31.89
Hail shock	Shock_hail	671		
Yes			81	12.07
No			590	87.93
Wind shock	Shock_wind	671		
Yes			251	37.41
No			420	62.59
Flood shock	Shock_flood	671		
Yes			79	11.77
No			592	88.23
Input price increase	Shock_input_price_increase	671		
Yes			612	91.21
No			59	8.79
Product price decrease	Shock_product_price_decrease	671		
Yes			248	36.96
No			423	63.04
Food consumption cost increase	Shock_food_cost_increase	671		
Yes			626	93.29
No			45	6.71
Worst shock experienced	Worst_shock	671		
Loss of harvest			5	0.75
Loss of livestock			33	4.92
Biological shock			9	1.34
Input price increase			109	16.24
Product price decrease			6	0.89
Food consumption cost increase			45	6.71
Economic shock			18	2.68
Information source	Information_source_ammonium_nitrate	671		
Yes			20	2.98
No			651	97.02

Most respondents are farm owners, with an average landholding of 5.8 ha and the average age is 56 years. The used continuous variables related to the farmers' characteristics are summarized in Table 3.

Table 3. Continuous variables related to farmers' characteristics (n = 671).

Variables	**Variable name**	**Number of observations**	**Max**	**Min**	**Mean**	**Standard deviation**
Age (years)	Age	648	98	21	56.14	13.69
Total owned land (ha)	Total_owned_land_ha	671	95	0	5.80	7.73
Years of ammonium nitrate use	Years_using_ammonium_nitrate	671	0	50	5.99	9.11
Required skills for use	Required_skills_ammonium_nitrate	671	1	10	6.36	2.76
Ability to pay for ammonium nitrate	Ability_to_pay_ammonium_nitrate	671	1	10	4.19	2.36
Perceived ability to obtain	Ability_to_obtain_ammonium_nitrate	671	1	10	4.69	2.68
Distance to input market	Distance_to_input_market	667	0	140	15.19	12.02

Linking farmers and farm characteristics to ammonium nitrate fertilization decision

In Kairouan and Zaghouan, 42% and 49% of farmers respectively use ammonium nitrate, while 64% and 70% plan to continue its use (Figure 3). Chi-square analysis reveals a significant but weak association between governorate and use. Lower adoption in Kairouan likely reflects its arid climate and limited rainfall (Hooper and Johnson, 1999), with soil conditions, infrastructure, and input access also influencing use (Swaney et al., 2018).

Among landowners, 46% currently apply ammonium nitrate and over 67% intend future use, whereas 72% of non-landowners do not use it and 52% have no future plans. Landownership significantly drives fertilizer adoption (Zondo and Baiyegunhi, 2021), with farm size positively linked to nitrogen application. Market distance shows a weak correlation with use, but road proximity has no effect.

Gender disparities persist: only 27% of women currently use ammonium nitrate compared to 45% of men, and intentions are 46% versus 67% (Figure 3). These gaps, which are statistically significant (at 5% for current use and 1% for future use), are consistent with documented gender inequalities in land access and inheritance in similar contexts (Agarwal, 2003; Yokying and Lambrecht, 2019). However, given the small number of women in our sample and the absence of detailed measures on education, we cannot attribute these differences solely to gender and instead interpret them as reflecting broader structural and cultural constraints faced by women. The possession of an agricultural degree and age show no significant effects: having an agricultural degree does not influence use, diverging from findings that education enhances fertilizer management (Kimaru-Muchai et al., 2012), and age differs from evidence linking higher adoption to farmers aged 35–44 (Tang and Yang, 2019).

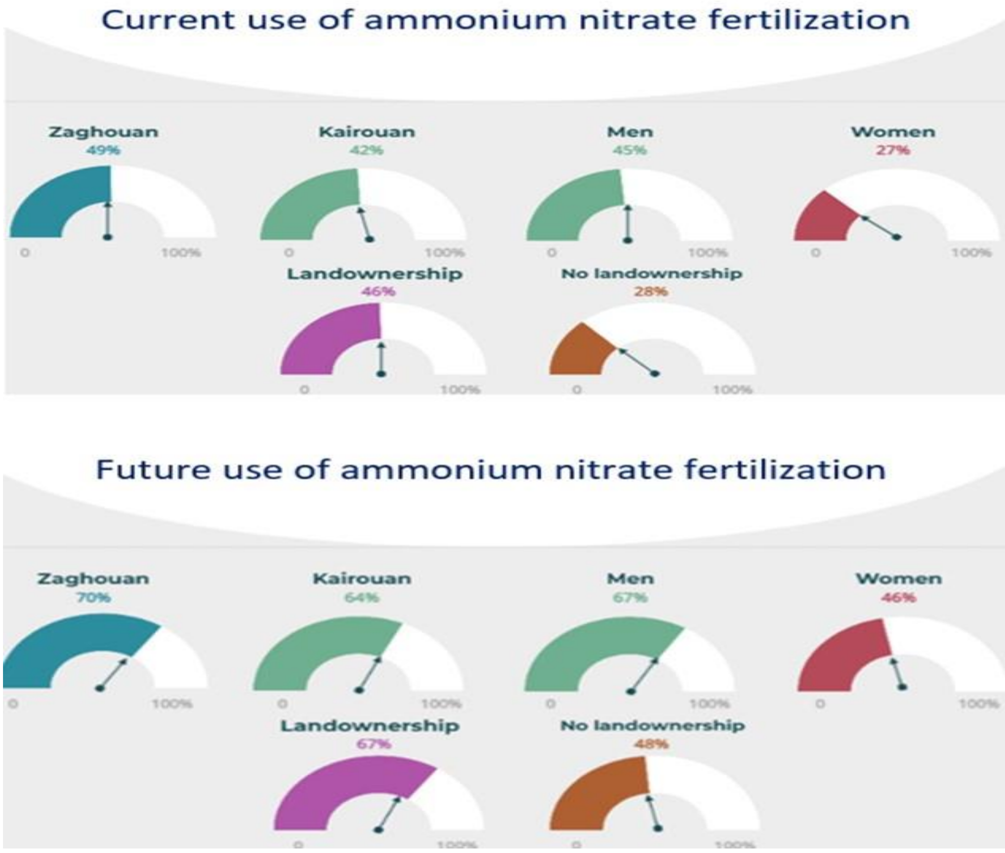

Figure 3. Current and future use of ammonium nitrate fertilization for barley by location, gender, and landownership.

Influence of climatic and economic shocks on the ammonium nitrate fertilization decision

Table 4 and the inspection of the cross-tabulated proportions show that input price increases have the strongest current association with ammonium nitrate use (p = 0.008, Cramér's V = 0.1020), followed by temperature rises (p = 0.023) and marginal significance for hail (p = 0.071). For future intentions, drought exhibits a strong correlation (p = 0.000, Cramér's V = 0.1466), suggesting farmers anticipate increasing use under dry conditions, while rising temperatures are negatively and weakly linked (p = 0.034, Cramér's V = −0.0817). Input price increases and declining production prices show near-significant effects, indicating adjustments to maintain yields amid financial pressures. Drought's role supports Gous et al. (2015), who highlight that water availability enhances fertilizer efficiency. Farmers may even increase use after rainfall shocks, as noted in India (Bora, 2022). Temperature-driven reductions align with Kenyan findings (Jagnani et al., 2021), while wind and flooding have no effect (Auffhammer and Carleton, 2018). Overall, drought and temperature emerge as key climatic determinants, consistent with Atinga et al. (2024), who observed that weather shocks reduce fertilizer amounts but not use. Economically, rising input and falling output prices significantly shape fertilizer decisions (Pender et al., 2004), with recent global price spikes (linked to the Russia–Ukraine war) worsening fertilizer access, productivity, and food security for smallholders (Jones and Nti, 2022).

Table 4. Climatic and economic shock associations with the future and current use of ammonium nitrate fertilizer.

	Variables	Pearson chi^2	Chi^2 significance	Cramér's V
Future use of ammonium nitrate versus	**Drought***	14.4147	0.000	0.1466
	Temperature increase	4.4805	0.034	−0.0817
	Hail	2.0554	0.152	−0.0553
	Wind	0.3412	0.559	−0.0226
	Flood	1.2390	0.266	−0.0430
	Input price increasing*	3.1243	0.077	0.0682
	Production price decreasing*	3.1746	0.075	0.0688
	Consumption price increasing	0.0026	0.959	−0.0020
Current use of ammonium nitrate versus	Drought	2.5940	0.107	0.0622
	Temperature increase	5.1505	0.023	0.0876
	Hail*	3.2547	0.071	−0.0696
	Wind	1.5069	0.220	0.0474
	Flood	1.8649	0.172	−0.0527
	Input price increasing*	6.9765	0.008	0.1020
	Production price decreasing	0.9335	0.334	0.0373
	Consumption price increasing	1.7953	0.180	0.0517

Notes: (1) asterisks indicate significance: *** 1%, ** 5%, and * 10%. Source: Author's elaboration from analysis of field data. (2) the "Cramér's V" column reports the effect-size measure of association produced by Stata, which in some cases preserves the sign of the underlying association (phi-like) and can therefore take negative values. In line with the standard definition of Cramér's V as a measure of association strength, we interpret these values in terms of their magnitude only (0–1), and infer the direction of the relationship from the cross-tabulated proportions.

Logistic regression analysis of current and future ammonium nitrate use

Descriptive analysis identified key variables influencing ammonium nitrate use for barley, incorporated into logistic regression models for current and future decisions. Multicollinearity diagnostics indicated no serious collinearity problem, as all VIF values remained below the conventional threshold (Table 5). Both models are statistically significant, with pseudo-R^2 values of 0.282 and 0.440, indicating moderate explanatory power. Table 6 presents Model 1 for current use and Model 2 for future intention.

Table 5. Multicollinearity diagnostics using VIF.

Model 1: Current Use of ammonium nitrate	**Collinearity Statistics**		**Model 2: Current Use of ammonium nitrate**	**Collinearity Statistics**	
	Tolerance	**VIF**		**Tolerance**	**VIF**
Constant			Constant		
Distance to Input Market	**,909**	**1,101**	Governorate	**,890**	**1,124**
Possession of Agriculture Degree	**,955**	**1,047**	Distance to Input Market	**,956**	**1,046**
Age	**,913**	**1,095**	Possession of Agriculture Degree	**,915**	**1,093**
Gender	**,937**	**1,067**	Age	**,940**	**1,063**
Farm Ownership	**,862**	**1,160**	Gender (Male)	**,907**	**1,102**
Total Owned Land	**,905**	**1,104**	Total Land Owned	**,852**	**1,174**
Governorate	**,804**	**1,243**	Total Barley Value	**,891**	**1,123**
Total Barley Value	**,870**	**1,149**	Years of Ammonium Nitrate Use	**,599**	**1,669**
Access Perception	**,486**	**2,056**	Perceived Skill Level	**,590**	**1,694**
Labor Perception	**,524**	**1,910**	Ability to Pay	**,755**	**1,324**
Knowledge Perception	**,611**	**1,636**	Perceived ability to obtain	**,536**	**1,867**
Perceived Skill Level	**,668**	**1,498**	Worst Shock: Loss of Harvest	**,805**	**1,242**
Ability to Pay	**,657**	**1,522**	Worst Shock: Loss of Livestock	**,962**	**1,040**
Perceived ability to obtain	**,443**	**2,256**	Worst Shock: Biological Shock	**,954**	**1,049**
Dependency on Environment	**,709**	**1,411**	Worst Shock: Input Price Increase	**,970**	**1,031**
Shock: Drought	**,875**	**1,143**	Worst Shock: Consumption Cost Increase	**,923**	**1,084**
Shock: Temperature	**,665**	**1,504**	Worst Shock: Economic Shock	**,944**	**1,059**
Shock: Hail	**,801**	**1,248**	Benefits	**,942**	**1,062**
Shock: Wind	**,421**	**2,378**	Non-use Reason: Limited Land	**,717**	**1,395**
Shock: Flood	**,835**	**1,197**	Non-use Reason: Limited Information	**,767**	**1,305**
Shock: Input Price Increase	**,733**	**1,364**	Non-use Reason: Low Yield	**,806**	**1,240**
Shock: Product Price Decrease	**,759**	**1,318**	Non-use Reason: Lack of Labor	**,699**	**1,431**
Shock: Consumption Cost Increase	**,775**	**1,291**			
Information Source: NGO/Gov.	**,923**	**1,083**			
Worst Shock: Input Price Increase	**,741**	**1,349**			

Table 6. Logistic regression models for future and current use of ammonium nitrate fertilization in barley farming.

Model 1: Current Use of Ammonium Nitrate				**Model 2: Future Use of Ammonium Nitrate**			
Variable description	**Coefficient**	**Odd Ratio**	**Std.err.**	**Variable description**	**Coefficient**	**Odd ratio**	**Std.err.**
Distance to Input Market	0.019*	1.018795	0.010237	Governorate (Kairouan)	−0.229	0.795022	0.2151224
Possession of Agriculture Degree	0.382	1.4657	0.691997	Distance to Input Market	0.028**	1.028447	0.0129783
Age	−0.016*	0.9839222	0.008354	Possession of Agriculture Degree	−0.955*	0.3849394	0.1995727
Gender (Male)	0.548	1.730226	0.850906	Age	−0.012	0.9876316	0.009009
Farm Ownership	0.348	1.415613	0.6294	Gender (Male)	0.782	2.185928	1.111334
Total Owned Land	0.015	1.015263	0.014453	Total Land Owned	0.003	1.002878	0.0170528
Governorate (Kairouan)	−0.585**	0.5570834	0.138449	Total Barley Value	0.0003	1.000318	0.0003388
Total Barley Value	0.0003*	1.000294	0.000171	Years of Ammonium Nitrate Use	0.15***	1.161873	0.0476119
Access Perception (Good)	−0.106	0.8997272	0.383877	Perceived Skill Level	0.1*	1.105806	0.0634962
Access Perception (Bad)	−0.965**	0.381159	0.174337	Ability to Pay	0.167**	1.181829	0.0820603
Access Perception (Very Bad)	−1.259**	0.2840003	0.148379	Perceived ability to obtain	0.018	1.018136	0.0303101
Labor Perception (Low)	0.926	2.523579	1.182443	Worst Shock: Loss of Harvest	−1.43	0.2394131	0.3230558
Labor Perception (High)	0.777*	2.174208	0.984982	Worst Shock: Loss of Livestock	−1.072*	0.3424199	0.198873
Labor Perception (Very High)	0.452	1.571634	0.718316	Worst Shock: Biological Shock	0.101	1.107445	1.377595
Knowledge Perception (Low)	−0.778	0.4593417	0.225586	Worst Shock: Input Price Increase	−1.574***	0.2074812	0.093267
Knowledge Perception (High)	0.08	1.083301	0.495412	Worst Shock: Consumption Cost Increase	−1.68***	0.1864261	0.0917291
Knowledge Perception (Very High)	0.547	1.727511	0.831043	Worst Shock: Economic Shock	−2.002**	0.1351696	0.1032496
Perceived Skill Level	0.317***	1.37267	0.083845	Benefits: Saves Money	1.303	3.680435	6.88884
Ability to Pay	0.274***	1.314693	0.077299	Benefits: Saves Labor	2.075	7.961383	14.10677
Perceived ability to obtain	−0.046	0.95505	0.059941	Benefits: Higher Yields	2.837**	17.04643	19.20495
Dependency on Environment	0.46***	1.584198	0.243413	Benefits: Drought Resistance	2.818**	16.744	21.62186
Shock: Drought	−1.225	0.2936846	0.314191	Benefits: Negotiability	3.289**	26.80107	32.7647
Shock: Temperature	−0.257	0.7736177	0.218274	Non-use Reason: Limited Land	−2.647***	0.0709096	0.0317245
Shock: Hail	−0.892**	0.409764	0.157218	Non-use Reason: Limited Information	−2.44***	0.0871942	0.0386978
Shock: Wind	1.005***	2.732066	0.982745	Non-use Reason: Low Yield	−0.859*	0.423567	0.1983165
Shock: Flood	−0.257	0.773349	0.295827	Non-use Reason: Lack of Labor	−1.103***	0.331837	0.123536
Shock: Input Price Increase	0.934*	2.545063	1.224093				
Shock: Product Price Decrease	−0.176	0.838339	0.205944				
Shock: Consumption Cost Increase	0.664	1.942475	0.948044				
Information Source: NGO/Gov.	1.711**	5.533409	4.329606				
Worst Shock: Input Price Increase	0.712*	2.03836	0.771905				

Asterisks indicate significance level: *** 1%, ** 5%, and * 10%.

Model 1: Current Use

Current use is mainly associated with access, experience, financial capacity, shocks, and information support. Farmers who received information from NGOs or government programs were more likely to use ammonium nitrate, suggesting that external information strongly supports actual adoption. Likewise, perceived skill level, ability to pay, and dependency on the environment increased the likelihood of current use, indicating that both capability and production context matter. Among the shocks, wind and input price increases were positively associated with current use, whereas hail had a negative effect. This suggests that farmers may use ammonium nitrate as a response to environmental risk and input-market pressure, but hail shocks may discourage use because of crop damage and reduced expected returns. Distance to input markets had only a small positive effect, showing a weak but significant access-related influence.

Model 2: Future intention

Future intention is more strongly shaped by perceived benefits and perceived constraints. A degree in agriculture reduced the probability of future use, which may reflect greater awareness of alternative nutrient-management practices or concerns about ammonium nitrate. Farmers who perceived higher yields, drought resistance, and negotiability were much more likely to plan future use, showing that expected performance is central to intention. By contrast, limited land, limited information, lack of labor, and weak yield expectations reduced future use intentions. Economic shocks such as input price increases and higher consumption costs also discouraged future plans, confirming that anticipated financial pressure reduces willingness to continue with ammonium nitrate. Overall, future intention depends less on basic demographics and more on perceived advantages and constraints. The results indicate that current use is more strongly shaped by experience, access, and immediate constraints, whereas future intention is driven more by perceived benefits and expected risks. This pattern confirms that farmers' decisions combine practical capacity with expectations about long-term performance.

6. Conclusions

This study shows that Tunisian farmers' decisions regarding ammonium nitrate use for barley are shaped primarily by perceptions, access to information, financial capacity, and exposure to economic and climatic shocks. The results also show an important distinction between current use and future intention: current use is more closely linked to immediate constraints and practical conditions, whereas future intention depends more on perceived benefits and expected barriers. These findings suggest that policies aimed at improving ammonium nitrate use in dryland areas should focus on strengthening access to reliable information, improving farmers' capacity to afford inputs through credit and subsidies, ensuring stable market prices, and reducing vulnerability to shocks. Targeted extension services, risk-management measures, and interventions adapted to local conditions may be particularly useful for supporting more informed and resilient fertilizer decisions. The study has some limitations. It relies on self-reported perceptions, which may be subject to response bias, and it does not include all potential determinants of ammonium nitrate use. Future research could incorporate additional institutional, agronomic, and agro-ecological factors and extend the analysis to other regions of Tunisia.

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