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Conservation agriculture adoption barriers and enabling factors among smallholder farmers

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Abstract

Nearly 68% of the world's farms are smaller than two hectares, yet adoption of conservation agriculture (CA) on these holdings remains below 15% in most developing regions. A structured household survey was administered to 384 smallholder cereal and legume growers across three provinces of central Spain (Castilla-La Mancha, Castilla y León, and Extremadura) between March and November 2021. Respondents ranked barriers and enabling factors on five-point Likert scales. Lack of technical information topped the barrier list (28.3%), followed by high labour demand (22.7%) and land tenure insecurity (17.4%). Among enabling factors, extension services and NGO support scored highest for farmers with less than one hectare, while subsidy programmes and market access mattered more for those above five hectares. Binary logistic regression showed that farm size, years of formal education, and access to farmer-to-farmer networks were the strongest predictors of CA adoption (pseudo- $R^2 = 0.47$). These findings point to the need for size-differentiated extension strategies rather than blanket promotion campaigns.

Keywords: Conservation agriculture, smallholder farmers, adoption barriers, enabling factors, extension services, land tenure, logistic regression, Likert scale, central Spain, farm size

Introduction

About 1.5 billion people depend on smallholder agriculture for their livelihoods, and soil degradation threatens roughly a third of those farms ^[1]. Conservation agriculture—built on minimal tillage, permanent soil cover, and crop rotation—offers a tested pathway to reverse that degradation ^[2]. But adoption rates remain stubbornly low in many regions. A 2019 global estimate put CA coverage at 205 million hectares, with over 70% concentrated in five countries where large-scale mechanised farming dominates ^[3].

Why do smallholders lag behind? Published explanations tend to cluster around economic constraints, information gaps, and socio-cultural factors ^[4, 5]. Yet most adoption research has focused on sub-Saharan Africa and South Asia, leaving semi-arid Mediterranean Europe underexplored—despite the fact that Spain's dryland smallholders face comparable challenges of water scarcity and thin soils ^[6]. This research surveyed 384 smallholder farmers across three provinces of central Spain to identify the main barriers to CA adoption and the factors that enable it, with special attention to how these differ by farm size.

Research area description

The survey covered three provinces: Castilla-La Mancha, Castilla y León, and Extremadura, collectively spanning the central meseta of Spain. The region experiences a continental Mediterranean climate with hot dry summers (mean July temperature 28–34 °C) and cold winters (mean January 3–6 °C). Annual rainfall ranges from 350 to 500 mm, concentrated in autumn and spring. Dominant crops include winter wheat, barley, sunflower, and chickpea on Calcisol and Cambisol soils.

Material and methods

Material

A structured questionnaire with 47 items was developed following established agricultural adoption frameworks ^[7]. It included sections on household demographics, farm characteristics,

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CA awareness, perceived barriers (12 items), and enabling factors (10 items), each scored on five-point Likert scales. The questionnaire was pre-tested with 30 farmers in Toledo province during February 2021 and revised for clarity. Sampling was stratified by province and farm size category (< 1 ha, 1–3 ha, 3–5 ha, > 5 ha), targeting a minimum of 384 respondents based on Cochran's formula at 95% confidence and 5% margin of error [8].

Methods

Face-to-face interviews were conducted between March and

November 2021 by trained enumerators at village markets, agricultural cooperatives, and irrigation association meetings. Responses were coded and entered into SPSS v27. Descriptive statistics summarised barrier and enabler rankings. Cronbach's alpha for the barrier scale was 0.83 and for the enabler scale 0.79, both above the 0.70 threshold. Binary logistic regression modelled CA adoption (yes/no) against 11 predictor variables including age, education, farm size, land tenure, access to credit, extension contact, and cooperative membership. Model fit was assessed by the Hosmer–Lemeshow test and Nagelkerke pseudo- R^2 .

Results

Table 1: Ranking of perceived barriers to conservation agriculture adoption (n = 384)

Rank	Barrier	Mean Score	SD	% Citing as Top
1	Lack of technical information	4.31	0.72	28.3
2	High labour demand	4.08	0.81	22.7
3	Land tenure insecurity	3.87	0.93	17.4
4	Limited access to CA inputs	3.64	0.88	14.8
5	Market uncertainty	3.21	0.96	9.6
6	Cultural resistance	2.94	1.03	7.2

Lack of technical information was the top-ranked barrier with a mean score of 4.31 out of 5 (Table 1). High labour demand ranked second, reflecting concerns about manual residue management without access to specialised equipment. Land

tenure insecurity ranked third—farmers on rented land showed significantly less willingness to invest in long-term soil-building practices ($p < 0.01$).

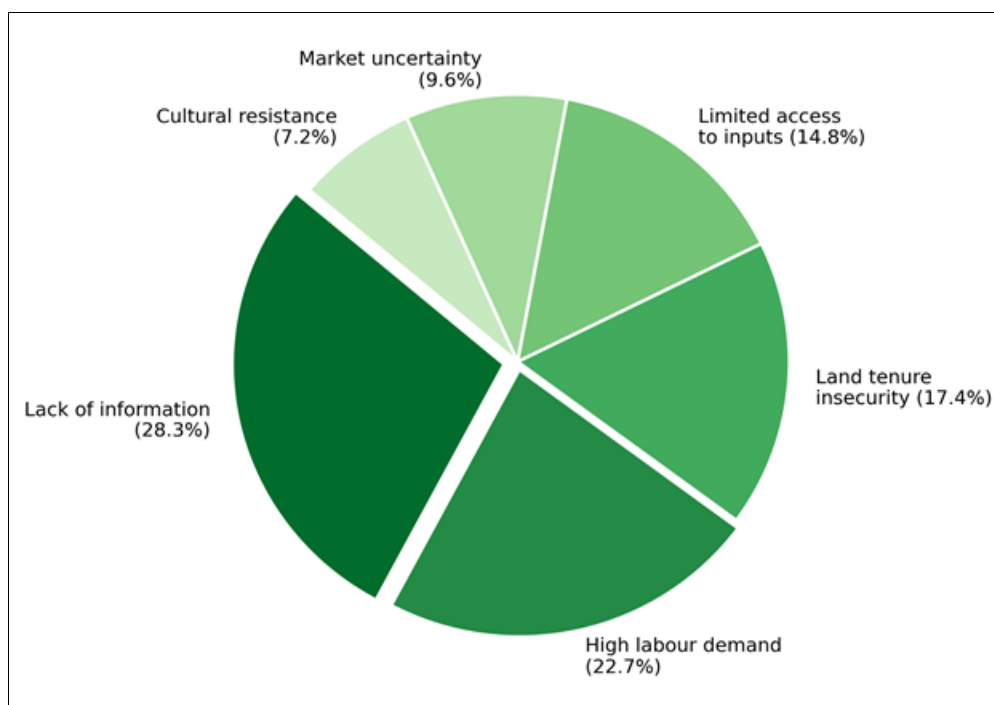


Fig 1: Proportional distribution of perceived barriers to conservation agriculture adoption among surveyed smallholder farmers

Table 2: Binary logistic regression results for CA adoption (n = 384)

Predictor	B	SE	Wald	p-value	Exp(B)
Farm size (ha)	0.68	0.19	12.81	< 0.001	1.97
Education (years)	0.43	0.14	9.44	0.002	1.54
Farmer network access	1.12	0.31	13.06	< 0.001	3.06
Extension contact	0.87	0.26	11.21	0.001	2.39
Land tenure (owned)	0.59	0.22	7.19	0.007	1.80
Age (years)	−0.03	0.01	5.67	0.017	0.97

Logistic regression (Nagelkerke pseudo- $R^2 = 0.47$; Hosmer–Lemeshow $p = 0.63$) identified farmer network access as the

strongest single predictor of adoption ($\text{Exp(B)} = 3.06$). Each additional hectare nearly doubled the odds of adoption (Exp(B)

= 1.97), and each year of education raised the odds by 54%.

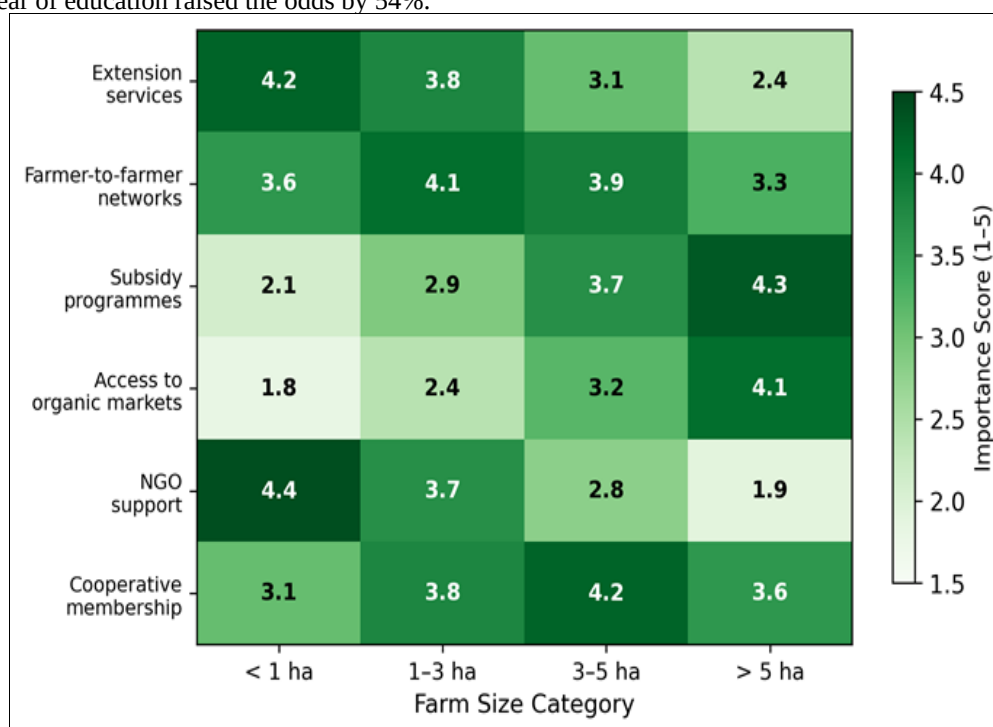


Fig 2: Importance scores of enabling factors for CA adoption stratified by farm size category

Comprehensive interpretation

The heatmap reveals a clear size-dependent pattern: the smallest farms (<1 ha) rely most on extension services and NGO support, while larger holdings (>5 ha) value subsidy programmes and market access more highly. Cooperative membership was rated consistently across all size groups, suggesting it functions as a cross-cutting enabler.

Discussion

The prominence of information gaps as the top barrier aligns with findings from Kenya and Bangladesh^[4, 9] but contrasts with Latin American research where input cost often leads^[10]. In the Spanish context, the dismantling of regional extension offices after 2008 budget cuts likely amplified the problem^[11]. That farmer-to-farmer networks emerged as the strongest adoption predictor ($\text{Exp}(B) = 3.06$) points to peer learning as a cost-effective substitute when formal extension falters.

Land tenure insecurity ranked third, confirming earlier Mediterranean work^[6]. Farmers renting land on short-term contracts (< 3 years) scored significantly lower on willingness to adopt minimum tillage, likely because the soil-quality benefits accrue over 5–7 years and the tenant may not be present to reap them. The negative coefficient for age (-0.03) suggests younger farmers are marginally more open to CA, though the effect size was small.

Conclusion

This survey of 384 smallholder farmers across central Spain identified lack of technical information, high labour demand, and land tenure insecurity as the three main barriers to conservation agriculture adoption. Farm size, education, and farmer network access were the strongest adoption predictors. Extension strategies should be differentiated by farm size: smaller holdings benefit most from hands-on demonstration and NGO partnerships, while larger ones respond to subsidy programmes and assured market channels. Securing longer land-lease terms could also remove a structural barrier for tenant

farmers.

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