THE DETERMINANTS AND CONSTRAINTS OF THE TRANSITION TO AGROECOLOGY IN ALGERIA. CASE OF MARKET GARDENS IN THE COMMUNE OF BOU ISMAIL (TIPAZA PROVINCE)

AZ AGROÖKOLÓGIÁRA VALÓ ÁTÁLLÁS MEGHATÁROZÓI ÉS KORLÁTAI ALGÉRIÁBAN: A BOU ISMAIL KÖZSÉG PIACI KERTJEI ESETE (TIPAZA MEGYE)

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ABSTRACT

Conventional farming, focused primarily on maximizing productivity, has led to adverse consequences for the environment and human health. Faced with these challenges, agroecology emerged as a promising alternative for sustainable agricultural practices that respect people's health and the environment. This study aims to determine whether agroecological practices are being adopted in the market gardening sector in the commune of Bou Ismaïl, identifying the factors influencing this adoption and defining the constraints hindering their development. To achieve this objective a survey of 33 randomly selected market gardeners was conducted to collect data on their characteristics and the agroecological practices implemented in their production processes. The data were analyzed using SPSS software and a Logit regression model. Findings reveal that while agroecological practices are being adopted in the study area, their adoption levels vary among farmers. The analysis identified several factors influencing this adoption, which are both internal and external to the farms and differ depending on the specific practices considered. However, the study highlights various constraints that hinder the adoption of agroecological methods. Based on these findings, recommendations are proposed to promote agroecological practices and enhance their adoption levels among market gardeners.

ABSZTRAKT

A hagyományos gazdálkodás, amely elsősorban a termelékenység maximalizálására fókuszál, súlyos negatív következményekhez vezetett a környezetre és az emberi egészségre nézve. Ezekkel a kihívásokkal szembenézve az agroökológia egy ígéretes alternatívaként jelent meg a fenntartható mezőgazdasági gyakorlatok között, melyek tiszteletben tartják az emberek egészségét és a környezetet. A tanulmány célja annak meghatározása, hogy az agroökológiai gyakorlatokat alkalmazzák-e a Bou Ismaïl község piaci kertészeti szektorában, az elfogadást befolyásoló tényezők azonosítása, valamint a fejlődést gátló korlátok meghatározása. E cél elérése érdekében 33 véletlenszerűen kiválasztott piaci kertész körében készítettünk felmérést, mely során adatokat gyűjtöttünk az egyének jellemzőiről és a termelési folyamatokban alkalmazott agroökológiai gyakorlatokról. Az összegyűjtött adatokat SPSS szoftver és egy Logit regressziós modell segítségével elemeztük. Az eredmények azt mutatják, hogy bár az

agroökológiai gyakorlatokat egyre inkább alkalmazzák a vizsgált területen, az elfogadás mértéke jelentősen eltér a különböző gazdák között. Az elemzés több, a gazdaságon belüli és azon kívüli tényezőt is azonosított, amelyek az agroökológiai gyakorlatok elfogadását befolyásolják, és ezek a tényezők a konkrét gyakorlatok függvényében változnak. Ugyanakkor a tanulmány számos olyan korlátot is feltár, amelyek akadályozzák az agroökológiai módszerek szélesebb körű elfogadását. Az eredmények alapján javaslatokat fogalmazunk meg az agroökológiai gyakorlatok előmozdítására és azok elfogadási szintjének növelésére a piaci kertészek körében.

INTRODUCTION

Over the past fifty years, rapid and profound changes have been induced in ecosystems, surpassing any other era in human history. A major driver of this transformation is the agricultural model shaped by modernization and inherited from the industrial paradigm. This model is characterized by the intensive use of chemical inputs, unsustainable soil exploitation, reliance on a narrow diversity of high-yield cultivars, and unsuitable irrigation techniques. These practices have led to significant environmental, ecological, and health consequences (Shelton et al., 2014; Hayes et al., 2011). The negative impacts are particularly pronounced in vegetable farming, where large quantities of mineral fertilizers and inappropriate pesticides are often used to grow fruits and vegetables.

Growing awareness of the adverse effects of conventional agriculture began in the 1980s, marking the emergence of agroecology as a promising alternative capable of addressing the challenges confronting conventional agriculture. Agroecology advocates for a more integrative approach, viewing food systems as a whole rather than focusing solely on isolated agricultural parameters aimed at maximizing food production. This paradigm emphasizes an agricultural system that is no longer reliant on intensive chemical and energy inputs but instead focuses on optimizing the use of an ecosystem's natural resources without depleting their regenerative capacity (Davis et al., 2012). In Algeria, despite the

presence of a significant and diverse peasant agricultural sector, agroecology remains underdeveloped compared to neighboring North African countries (Willer et al., 2022). The absence of incentives and the delays in implementing policies to support sustainable agriculture have perpetuated conventional farming practices, which key stakeholders often perceive as ensuring stable yields through the reliance on synthetic inputs. This context highlights the urgent need for stakeholders at multiple levels to recognize the risks associated with synthetic inputs, particularly their adverse impacts on human health and the environment, and to initiate a transition towards an agroecological system. In response to this challenge, the present study focuses on the agroecological transition in the commune of Bou Ismail, a region known for its intensive production of vegetable crops that depend heavily on chemical inputs. The study aims to investigate the adoption of agroecological practices, identify the factors incentivizing this transition, and address the constraints hindering their development. Based on these insights, the research seeks to establish actionable recommendations to promote more sustainable agricultural practices that prioritize environmental preservation and public health.

MATERIALS AND METHODS

Study area

The commune of Bou Ismail, located in the fertile Mitidja Plain in northern Algeria, is a key agricultural region with a Mediterranean subhumid climate and abundant water resources. Known for its greenhouse-based market gardening, it is a leading producer of high-demand crops that rely heavily on chemical inputs. This prominence in market gardening and the need to explore sustainable agricultural practices made Bou Ismail the ideal site for the study, alongside considerations of accessibility and logistical factors. The geographical location of the commune is shown in Figure 1.

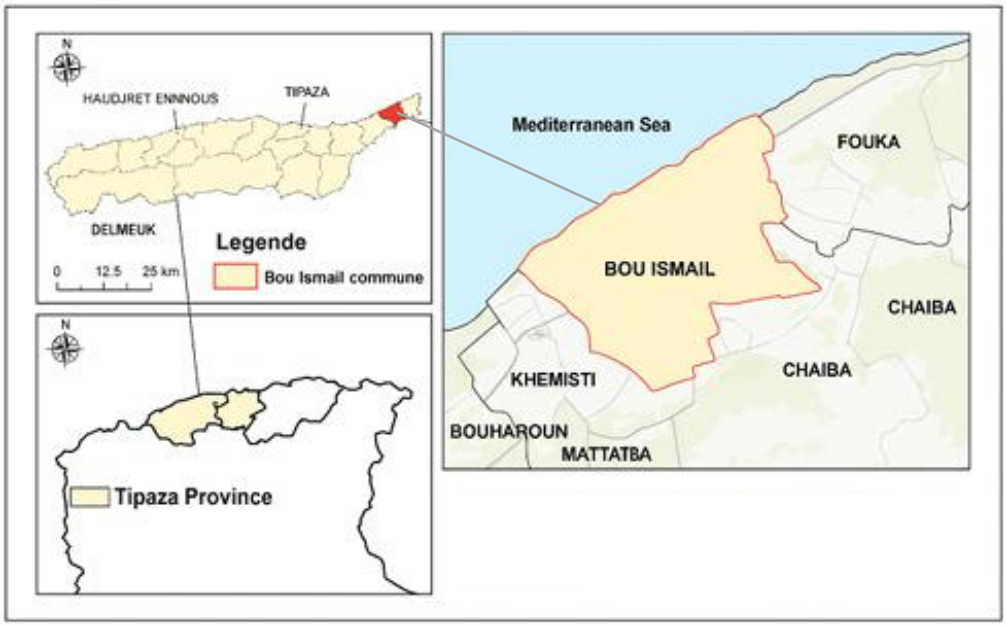

Figure 1. **Geographical Location of the Commune of Bou Ismail in Tipaza Province.**
Source: PDAU,2008

Data Collection and Sampling

To conduct our research, a mixed-methods approach was used to capture both general trends and individual perceptions of farmers. Qualitative interviews were conducted with key informants, such as market gardeners, relevant institutions, and NGO representatives, to gather valuable insights followed by quantitative surveys involving individual interviews with 33 farm owners, representing 30% of the total population. A purposive sampling strategy was employed where the farmers were intentionally selected based on their involvement in market gardening and interviewed using a structured questionnaire covering six main complementary sections: market Gardner identification, farm information, cropping system operations, access to credit and financing, risk perception and insights on agroecology.

To reinforce the validity of the data, on-site observations were conducted during farm visits, and triangulation techniques were used to cross-check the accuracy of

responses. The collected data were analyzed using SPSS software (version 26), Descriptive statistics were used to outline prevailing trends and constraints, while logistic regression analysis helped identify the main factors influencing the adoption of agroecological practices among surveyed farmers.

CONCEPTUAL MODEL

The producers' decision to adopt innovations is grounded in the principle of rationality, particularly the hypothesis of utility maximization from neoclassical theory. According to this framework, adoption or intensification of an innovation occurs only when the anticipated profitability surpasses that of non-adoption or non-intensification (Marenya et al., 2007). A rational producer, therefore, opts for the agricultural practice that provides the highest utility. However, research increasingly demonstrates that the factors driving innovation adoption extend beyond the purely economic considerations outlined in neoclassical theory.

The shift toward agroecological practices illustrates the multifaceted nature of farmers' decision-making processes. Adoption is influenced not only by economic considerations but also by a broader range of structural, institutional, and personal factors. These include farm-specific characteristics, such as the type of production chain, prevailing market conditions, distribution networks, public agricultural policies, and associated costs. Equally important are the attributes of the producers themselves, including their age, farming experience, educational background, and personal values.

While economic and financial motivations are significant, numerous studies, such as Padel (2001), underscore the critical role of non-economic motivations in shaping these decisions. Factors such as health-related concerns, ethical and religious beliefs, societal values and environmental awareness (Clarke et al., 2008; Darnhofer et al., 2005; Conacher and Conacher, 1982). Among these, environmental awareness stands out as a pivotal determinant, with research

highlighting its significance in evaluating the likelihood of conversion among conventional farmers (Latruffe and Nauges, 2010; Burton et al., 1999).

To empirically capture and analyze this multi-dimensional decision-making process, researchers often employ binary discrete choice models, such as logit and probit models, which are well-suited for explaining dichotomous outcomes. In this context, the dependent variable typically takes the value of 1 for agroecological adoption and 0 for the continuation of conventional farming (Lohr and Salomonson, 2000; Pietola and Oude Lansink, 2001; Genius et al., 2006; Sauer and Park, 2009).

Building on this econometric framework, the present study employs the Logit model to explore the dynamics of agroecological adoption. The model's robustness and adaptability to diverse agricultural contexts have been confirmed by previous research (Issoufou et al.,2017; Roussy et al.,2015; Yabi et al.,2016), along with its capacity to capture the combined effects of diverse and interdependent factors making it a valuable tool for exploring the complex motivations and constraints influencing farmers' choices.

EMPIRICAL MODEL

In the context of this study, the dependent variables of the Logit models are the adoption of agroecological practices identified during the analysis of the collected data. These practices include crop rotation, intercropping, crop association, varietal diversity within the same plot, crop-livestock integration, soil coverage, the use of resistant crop varieties, the introduction of beneficial organisms, the use of organic alternatives to chemical fertilizers and the use of local seeds.

Based on the theoretical foundations outlined above and the findings of previous studies, particularly those by Padel (2001), McBride et al., 2003) and Yabi et al. (2016), as well as survey data, the factors likely to influence the probability of adopting these agroecological practices are summarized in Table 1.

Table 1. **Description and Descriptive Statistics of Variables Included in the Logit Models.**

Variables	Code	Quantitative variables		Qualitative variables	
		Mean	**Standard deviation**	**Values**	**Frequency**
Age	AGE	51,84	13,75		
Agronomic experience (years)	EXP	30,84	14,02		
Farm size (ha)	SUP	1,73	2,09		
Status of the farmer	STAT			1= owner 2= tenant 3= associate	19 (57,58) 14 (21,21) 14 (21,21)
Agricultural training	FORMA			1= yes 0= no	4 (12,12) 29 (87,88)
Presence of a plant nursery	PEPIN			1= yes 0= no	3 (09,09) 30 (90,91)
Presence of family workforce	ACTIF			1= yes 0= no	7 (21,21) 26 (78,79)
Access to credit	FINANC			1= yes 0= no	29 (87) 4 (13)
Awareness of environmental risks	ENV			1= yes 0= no	5 (15) 28 (85)
Awareness of health risks	SANT			1= yes 0= no	19 (57,57) 14 (42,43)
Access to agricultural extension services	VULG			1= yes 0= no	2 (06,06) 31 (93,93)
Contact with NGOs	NGO			1= yes 0= no	8 (24,24) 25 (75,75)
Membership in a professional organization.	ORGAN			1= yes 0= no	14 (42,42%) 19 (57,57%)

NB: The values in parentheses are relative frequency

Source: Own SPSS results, 2024

Model Specification

The empirical equation derived from the theoretical model is formulated as follows:

$$p(yi = 1) = \frac{1}{1+e-x}$$

where: $x = \beta 0 + \beta 1\ AGE + \beta 2\ FORMA + \beta 3\ EXP + \beta 4\ STAT + \beta 5\ SUP + \beta 6\ PEPIN + \beta 7\ ACTIF + \beta 8\ FINANC + \beta 9\ ENV + \beta 10\ SANT + \beta 11\ VULG + \beta 12$ NGO $+ \beta 13\ ORGAN$.

In this formulation:

- β0 represents the constant term
- βi are the coefficients to be estimated
- εi is the error terms.

In order to evaluate the quality and reliability of the model, several statistical techniques are employed. In this study, the p-value is used to test the overall significance of the model, indicating the likelihood of obtaining the observed results under the null hypothesis. The model is considered globally significant if the p-value is lower than the chosen significance threshold (1%, 5%, or 10%).

The signs of the estimated coefficients reveal the direction of influence that each independent variable exerts on the probability of adopting a particular agroecological practice. The statistical significance of each coefficient is crucial for interpreting the results, as it defines the level of confidence with which a variable's impact can be considered reliable.

All descriptive statistics and regression analyses were conducted using SPSS software, which provided both the estimation results and the significance levels for the explanatory variables.

RESULTS

Socio-demographic characteristics of market gardeners

The survey findings indicate that market gardening in the commune of Bou Ismaïl is predominantly a male-dominated occupation, with 97% of respondents being men. Women represented only 3%, typically working alongside their spouses. Land tenure varies across the sample: 57% of farmers are landowners, while the remaining respondents are evenly divided between tenants and associates.

Respondents ranged in age from 23 to 76 years, with a mean of 51.84 ± 13.75 years, and reported an average of 30.84 years of experience in vegetable production. In terms of education, 70% of farmers attended school: 42.42% completed middle school and 12.12% attained secondary education, whereas over 30% of respondents reported being illiterate.

Despite their extensive farming experience, formal agricultural training was rare. Only 12% had participated in structured agricultural programs while the vast majority (88%) had never received any formal instruction. For 94% of farmers, agriculture is the sole source of income, and the average cultivated land area per respondent was 1.73 ± 2.09 hectares.

When it comes to labor organization, 21% of farmers employed both family labor and hired workers, while 79% depended solely on hired labor. Access to formal financial services was notably absent, none of the surveyed farmers had access to formal agricultural credit. Instead, 87% relied on supplier credit, and 52% depended on financial support from family or friends.

Furthermore, 91% of farmers who lacked their own plant nursery reported purchasing seeds, mostly hybrid varieties, which are often ill-suited to local conditions, thus undermining both autonomy and sustainability.

Awareness of environmental risks associated with intensive agriculture remained low. While only 15% of respondents acknowledged such risks, 58% expressed awareness of the health hazards posed by chemical inputs.

Institutional engagement was limited: only 6% of farmers consulted environmental monitoring organizations, and just 25% had attended training activities led by NGOs. However, 42% of respondents reported membership in professional agricultural organizations.

Agroecological Practices

Agroecological practices exhibit varying levels of adoption among market gardeners. A significant proportion of farmers (82%) reported using varietal diversity within the same plot, while 27% adopted short-cycle cover cropping. For soil fertility management, all respondents combined chemical fertilizers with organic amendments, reflecting a hybrid approach. Additionally, 24% used algae-based organic fertilizers to minimize chemical input, and 15% practiced crop-livestock integration to produce organic manure.

Crop rotation emerged as one of the most widespread practices, with 91% of farmers implementing it; notably, 27% included leguminous crops such as beans to enhance soil fertility. Crop association was also widely practiced, with 58% of respondents combining different crops in the same field.

Weed management was a universal concern. All farmers relied on manual weeding, and 73% supplemented it with soil cover techniques to suppress weeds and retain moisture. Localized irrigation systems were used consistently across all farms.

Regarding pest control, most farmers depended on chemical methods, though one reported using biological control by introducing natural predators. Furthermore, 55% of farmers chose pest-resistant crop varieties. In terms of marketing strategies, 85% of producers sold their yields at wholesale markets.

These varied adoption rates point to a dynamic yet uneven transition toward agroecological practices. A summary of adoption levels for each technique is presented in Figure 2.

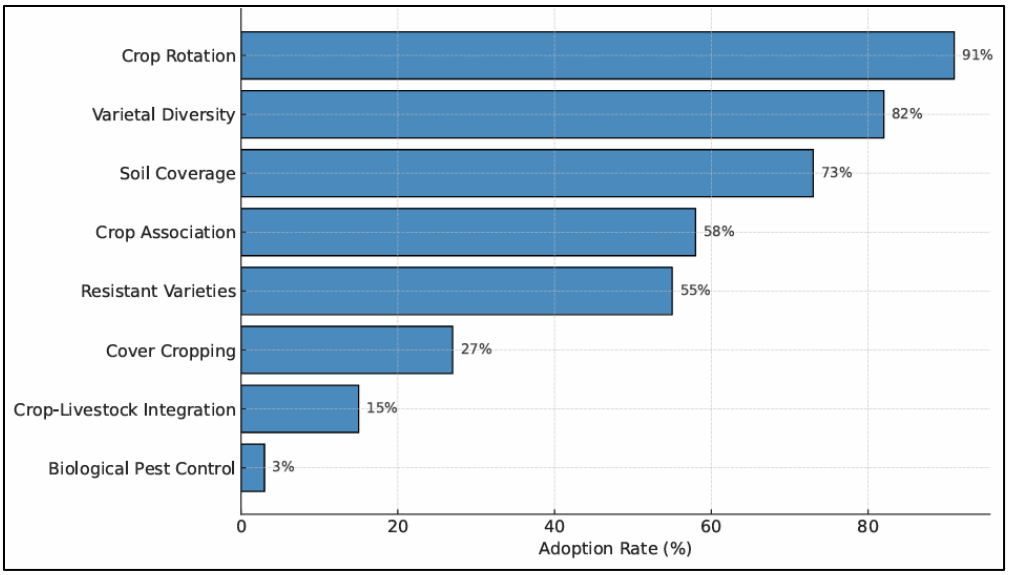

Figure 2. **Adoption of agroecological practices among market gardeners**
Source: Own SPSS results, 2024

Factors determining the adoption of agroecological practices

With the aim of providing a clear and structured overview of the main findings, a heatmap matrix (Figure 3) has been constructed in order to illustrate the statistically significant relationships between selected socioeconomic and institutional factors, and the adoption of the ten agroecological practices among market gardeners in the commune of Bou Ismail. Each row of the matrix corresponds to an agroecological practice, while each column represents a determinant tested in the logistic regression models.

The signs in the matrix indicate the direction of the relationship: a plus sign ("+") denotes a positive and significant effect, while a minus sign ("–") reflects a negative and significant effect. Blank cells indicate the absence of statistically significant results for the respective variable-practice pair.

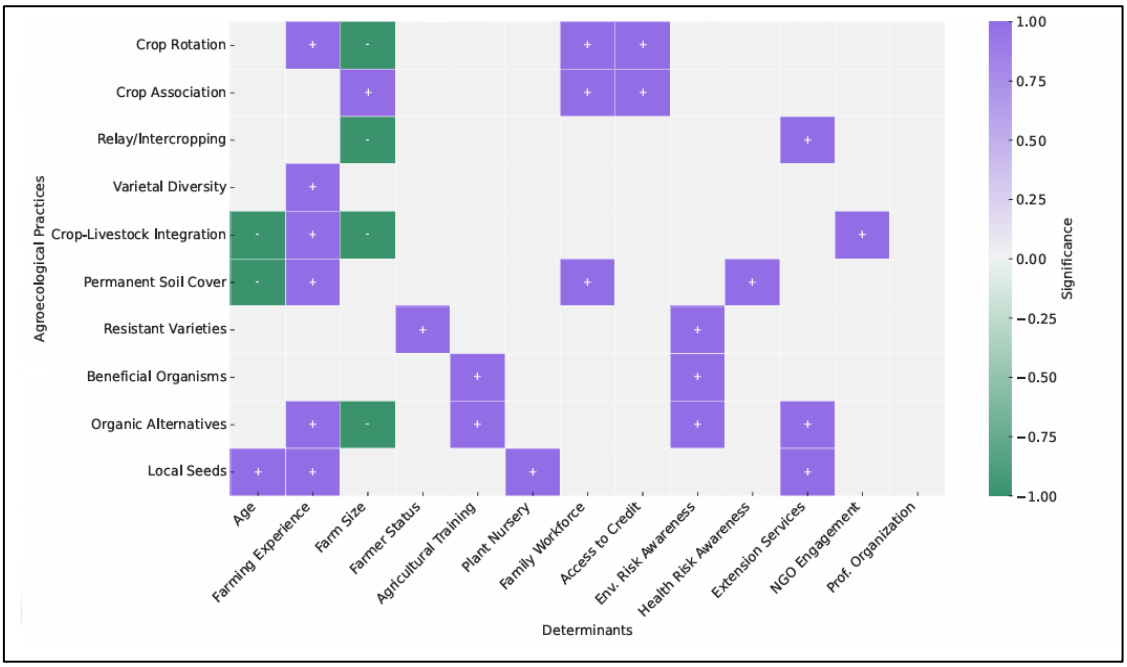

Figure 3. **Heatmap summarizing statistically significant determinants of agroecological practice adoption among market gardeners in Bou Ismail.**
Source: Own SPSS results, 2024

The heatmap matrix serves as a reference point for the detailed discussion that follows. Each agroecological practice is examined individually to identify and interpret the specific determinants that significantly influence its adoption, based on the results of the logistic regression analyses.

Determinants of crop rotation practice

The logistic regression model assessing the adoption of crop rotation is statistically significant at the 5% level ($p = 0.039$). Four key determinants show statistically significant effects at the 10% threshold: farm size, farming experience, presence of family workforce, and access to credit.

- Farm size has a negative and significant influence, suggesting that farmers operating larger landholdings are less likely to adopt crop rotation strategies.
- Farming experience positively affects adoption, indicating that more experienced farmers are more inclined to implement rotational practices.
- The presence of a family workforce also has a positive and significant impact, as farms supported by family labor are more likely to integrate crop rotation.
- Finally, access to credit significantly increases the likelihood of adoption, underscoring the enabling role of financial resources in facilitating this agroecological transition.

Determinants of crop association practice

The model estimating the factors influencing the adoption of crop association practices is statistically significant at the 5% threshold ($p = 0.04$). The logistic regression analysis identifies three key determinants that shape the likelihood of adoption: farm size, type of agricultural labor, and access to credit.

- Farm size has a positive and significant effect at the 5% level, indicating that farmers managing larger farms are more likely to adopt crop association practices.
- The type of agricultural labor also plays a role, with a combination of family and hired labor positively influencing adoption at the 10% level. This suggests that diversified labor resources support the integration of multiple crops.
- Access to credit emerges as a further determinant, positively influencing adoption at the 10% level. Farmers with better financial access are more likely to implement crop association as part of their cultivation strategy.

Determinants of relay cropping and intercropping practices

The model estimating the factors influencing the adoption of relay cropping and intercropping practices is statistically significant at the 5% level ($p = 0.023$). The regression analysis highlights two determinants that significantly influence the likelihood of adoption at the 10% threshold: farm size and access to agricultural extension services.

- Farm size exhibits a negative effect, indicating that farmers with larger landholdings are less likely to implement relay cropping and intercropping practices. This may be due to the complexity or labor-intensiveness of managing diversified systems on a large scale.
- In contrast, access to agricultural extension services has a positive and significant impact. Farmers who benefit from extension support and are exposed to training or technical information are more likely to adopt these practices.

Determinants of variety diversity within the same plot practice

The model assessing the factors influencing the adoption of varietal diversity within the same plot is statistically significant at the 5% threshold ($p = 0.023$). The logistic regression analysis identifies agricultural experience as the sole significant determinant.

- Years of agricultural experience have a positive and significant effect at the 5% level, indicating that farmers with more extensive farming experience are more likely to adopt varietal diversity within the same plot. This may reflect the accumulated knowledge and adaptive capacity of experienced farmers in managing crop variation.

Determinants of the practice of crop-livestock integration

The statistical analysis of the model evaluating the adoption of crop-livestock integration is significant at the 5% threshold ($p = 0.041$). Four key factors are identified as significantly influencing the probability of adoption: age, agricultural experience, farm size, and engagement with NGOs.

- Age negatively affects adoption at the 5% level, suggesting that younger farmers are more likely to implement crop-livestock integration practices.
- In contrast, years of agricultural experience has a positive and significant effect, indicating that more experienced farmers are better positioned to incorporate livestock into their farming systems.
- Farm size exhibits a negative influence at the 10% threshold, implying that farmers managing larger land areas are less likely to adopt this integrated approach.
- Lastly, engagement with NGOs, including schools and research institutions, positively affects adoption at the 10% level. This highlights the important role of external institutional support in promoting agroecological integration strategies.

Determinants of the adoption of permanent soil cover

The estimation model for the adoption of permanent soil cover is statistically significant at the 5% level ($p = 0.05$). The logistic regression identifies four key determinants: age, agricultural experience, awareness of health risks, and presence of family workforce.

- Age has a negative and significant effect at the 5% level, suggesting that younger farmers are more inclined to adopt permanent soil cover compared to their older counterparts.

- Conversely, agricultural experience positively influences adoption at the 5% threshold, indicating that experienced farmers are more likely to implement this soil management strategy.
- The presence of family workforce is positively associated with adoption at the 10% level. This implies that farms with family labor, particularly when combined with paid labor, are more capable of managing practices such as soil cover.
- Lastly, awareness of health risks related to chemical use exerts a positive influence at the 10% level, highlighting that farmers who recognize these risks are more likely to adopt soil-protecting practices.

Determinants of the adoption of resistant crop varieties

The estimation model for the adoption of resistant crop varieties is statistically significant at the 5% level ($p = 0.026$). The logistic regression identifies two key determinants that significantly influence adoption: farmer's status and environmental risk awareness.

- Farmer's status has a positive and significant effect, indicating that landowners are more likely to adopt resistant crop varieties compared to tenants or associates. This may reflect greater autonomy and willingness to invest in resilient agricultural inputs among owners.
- Awareness of environmental risks also exerts a positive influence at the 5% level, suggesting that farmers who are more conscious of ecological degradation are more inclined to incorporate resistant varieties into their farming systems.

Determinants of the introduction of beneficial organisms practice

The SPSS analysis reveals that the model estimating the factors influencing the adoption of beneficial organism introduction is statistically significant at the 5%

threshold (p = 0.05). Two variables are identified as having a significant positive effect on the adoption of this practice: agricultural training and environmental risk awareness.

- Agricultural training is significant at the 5% level, indicating that farmers who have received formal or informal agricultural education are more likely to introduce beneficial organisms into their production systems.
- Similarly, awareness of environmental risks is positively associated with adoption, also at the 5% level. This suggests that farmers who are more environmentally conscious are more inclined to seek sustainable alternatives such as biological pest control.

Determinants of the adoption of alternatives to chemical fertilizers

The model estimating the factors influencing the adoption of alternatives to chemical fertilizers is statistically significant at the 5% threshold (p = 0.042). The logistic regression identifies five key determinants: environmental risk awareness and agricultural training (significant at the 5% level), as well as farming experience, access to extension services, and farm size (significant at the 10% level).

- Awareness of environmental risks positively influences adoption, indicating that environmentally conscious farmers are more likely to seek and apply alternatives to synthetic inputs.
- Agricultural training also has a significant positive effect, suggesting that farmers who receive technical education are more inclined to adopt sustainable soil fertility practices.
- Years of farming experience are positively associated with adoption, reflecting that more experienced farmers tend to diversify input strategies.
- Access to extension services enhances adoption, with informed farmers showing greater willingness to transition toward organic or natural inputs.

- In contrast, farm size has a negative effect, implying that farmers operating larger land areas are less likely to adopt these alternatives, possibly due to scalability challenges or cost concerns.

Determinants of the adoption of local seeds

The results of the model estimating the factors influencing the adoption of local seeds are statistically significant at the 5% threshold ($p = 0.048$). The logistic regression identifies six key determinants that significantly affect adoption: presence of a plant nursery, farming experience, age, and access to agricultural extension services, all significant at the 5% level.

- The presence of a plant nursery on the farm strongly and positively influences adoption, suggesting that having access to a nursery facilitates the production and use of resilient local seed varieties.
- Years of farming experience is positively associated with adoption, indicating that experienced farmers are more likely to trust and utilize local seed resources.
- Farmer's age also shows a significant positive effect, suggesting that older farmers are more inclined to adopt traditional and localized practices such as using local seeds.
- Finally, access to agricultural extension services contributes positively to adoption, reinforcing the role of technical guidance and knowledge dissemination in supporting the use of local genetic resources.

DISCUSSION

Several authors have concluded that the factors determining the adoption of an innovation in rural areas are not only related to the technology itself but also to factors internal to the farm (such as the characteristics of the farmer and the farm) or external to the farm (including agricultural, economic, political, and

environmental contexts). After estimating the effects of various factors on the adoption of agroecological practices, the results show that these determinants may either encourage or discourage adoption, depending on the context and nature of the practice. To better situate these findings within existing research, Table 2 summarizes the significant determinants identified in this study and indicates whether they align with or diverge from previous literature.

Age and Experience

Age is widely recognized as a factor influencing farmers' willingness to adopt agroecological practices. Older farmers often show a lower inclination to transition to agroecology due to the challenges of adopting new techniques and the perception that they will soon exit the agricultural sector. This partly explains the negative impact of age on the adoption of practices such as crop association and permanent soil cover in our study area. Similar findings were highlighted by McBride and Greene (2009), who noted that older farmers lack incentives to invest human and material resources in new practices. However, age positively influences the use of local seeds, as this practice is deeply rooted in tradition and more familiar to older farmers, with experience further reinforcing this familiarity, as noted by Yabi et al. (2016).

Table 2. **Comparative Summary of Empirical Findings with Existing Literature**

Determinant	Effect in This Study	Aligned Studies	Contradictory Studies
Age	Negative (except for local seeds: positive)	McBride & Greene (2009), Yabi et al. (2016)	Adégbola & Adékambi (2008), Chanou (2007)
Experience	Positive for traditional practices	Yabi et al. (2016), Ouédraogo (2003)	Sall et al. (2000), Dakin (2008)
Farm Size	Mixed (mostly negative, positive for association/intercropping)	McBride et al. (2003), Genius (2006)	Pietola & Oude Lansink (2001), Gardebroek (2003)
Land Tenure	Positive	Yabi et al. (2016), Diogo et al. (2017)	—
Labor Availability	Positive	Dossa et al. (2018)	—
Training	Positive	Koesling et al. (2008), Genius et al. (2006)	—
Extension & NGOs	Positive for some practices	Roussy et al. (2015), Issoufou et al. (2017)	—
Environmental Awareness	Positive	Läpple (2010), Burton et al. (2003)	—
Health Risk Perception	Positive	Bellon & Lamine (2008)	—
Access to Credit	Positive for rotation & intercropping	Sale et al. (2014), Ouédraogo (2010)	—
Nursery	Positive for local seeds	Not widely explored	Not widely explored

Source: Own elaboration based on study results and synthesis of relevant literature.

While there is a general consensus on the influence of age, it is important to note that age is closely linked to other factors, such as agronomic experience. Experienced farmers tend to achieve higher economic performance, which can reduce the economic risks associated with innovation (e.g., financial losses or bankruptcy). However, this same experience can lead to resistance to change.

From the analysis of the results, it is evident that more experienced market gardeners are more inclined to adopt traditional practices such as the use of local seeds, crop rotation, permanent soil cover, and alternatives to chemical fertilizers,

as well as varietal diversity within plots. These findings align with previous studies, including those by Yabi et al. (2016), Ouédraogo (2003), and Zegeye et al. (2001), which emphasize that adopting new practices requires a certain level of risk-taking. Younger, less experienced farmers are generally more willing to take risks than their older counterparts, which partly explains the lower adoption rates of certain agroecological practices among older farmers. However, these findings contradict other studies, such as those by Adégbola and Adékambi (2008), Sall et al. (2000), Chanou (2007), and Dakin (2008), which suggest that older, more experienced farmers are more likely to adopt innovations. These contrasting perspectives may indicate that experienced farmers weigh the cost-benefit advantage of agroecological practices and are sometimes deterred by the lack of immediate effects (yabi et al, 2016). As a result, they may hesitate to fully commit to such practices.

Farm Size and Land Tenure

Farm size plays a significant role in shaping the adoption of agroecological practices as well. Larger farm sizes tend to reduce the likelihood of adopting practices such as crop rotation, alternatives to chemical fertilizers, and crop-livestock integration. According to Yabi et al. (2016), this can be attributed to the fact that owning land is one thing but effectively managing it using good agricultural practices is another. Implementing practices such as crop rotation, crop-livestock integration, and the use of alternatives to chemical fertilizers on larger plots requires substantial financial resources for input purchases, adequate equipment, and additional labor, particularly in the context of labor shortages. The adoption of agroecological practices also demands significant time, training, and effort. As highlighted by McBride et al. (2003), the additional labor costs associated with these practices can act as a barrier to adoption, even though some practices may ultimately reduce labor costs. Smaller farms, on the other hand, may find agroecological practices more appealing as they offer solutions to issues of

diseconomies of scale (McBride and Greene, 2009). Additionally, they are more likely to rely on family labor and face lower opportunity costs for conversion to agroecological methods (Genius, 2006).

However, farm size also has a positive influence on certain practices. Larger farms are more likely to adopt crop associations and short-cycle intercrops. This aligns with findings from studies by Pietola and Oude Lansink (2001) and Gardebroek (2003), which suggest that extensive production practices are more easily implemented on larger plots. These results highlight the dual nature of farm size's impact on the adoption of agroecological practices, where larger plots can both hinder and facilitate the transition, depending on the specific practices and the associated costs or benefits.

Farmers who own the land they cultivate demonstrate a greater inclination to adopt resistant crop varieties. This positive influence of land ownership, as highlighted by Yabi et al. (2016), underscores the critical role of land tenure security. Land ownership encourages farmers to implement practices aimed at preserving soil fertility and health over the medium and long term. Seminal studies, such as those by Diogo et al. (2017) and Amichi et al. (2016), have consistently emphasized the stabilizing effect of secure land tenure on investment decisions. Stable land ownership fosters a sense of stewardship, motivating farmers to adopt innovative agricultural technologies that support sustainable land management.

The type of agricultural labor

The type of agricultural labor, particularly the combination of family labor with permanent hired workers, significantly encourages the adoption of crop association and soil cover practices. This dynamic can be attributed to the labor-intensive nature of such practices. For instance, measures like the constant monitoring of intercropped fields and ongoing soil maintenance require substantial labor input, which can be financially burdensome if reliant solely on

hired labor. The availability of family labor helps offset these costs by increasing the pool of agricultural workers available to the farmer. This not only mitigates labor shortages but also reduces dependency on external labor, making it more feasible for farmers to adopt agroecological practices. This observation aligns with findings by Dossa et al. (2018), who highlighted that an increasing number of agricultural laborers within a farming operation enables producers to better meet the labor demands associated with such practices.

Training, Extension Services, and NGO Engagement

Agricultural training plays a pivotal role in fostering the adoption of agroecological practices, such as the use of local seeds and the introduction of beneficial organisms into farming systems. Trained farmers benefit from closer guidance, enabling them to gain advanced knowledge of agroecological techniques and a deeper understanding of the environmental and economic benefits associated with these practices. This finding aligns with existing agricultural research, where studies such as Koesling et al. (2008) highlight, through a multinomial model, that formal agricultural training, rather than general education, is a key driver of conversion to organic farming. Similarly, Genius et al. (2006) emphasize that the amount of agricultural information received, whether actively or passively, significantly increases the likelihood of adopting sustainable practices.

Access to agricultural extension services significantly promotes the adoption of several agroecological practices, including crop-livestock integration, the use of alternatives to chemical fertilizers, short-cycle intercropping with cover crops (particularly legumes), and the use of local seeds. Farmers who engage with NGOs have a higher likelihood of adopting crop-livestock integration, benefiting from tailored guidance and easier access to information and training on new technologies. The positive influence of agricultural extension services or NGO-led projects on the adoption of agricultural technologies has been well-

documented by several studies (Roussy et al., 2015; Yabi et al., 2016; Issoufou et al., 2017). Farmers connected to these extension structures receive close support, enabling them to acquire knowledge and skills related to innovative techniques (Issoufou et al., 2017), which in turn facilitates the adoption of agroecological innovations (Folefack et al., 2012). However, the lack of significant impact of these structures on the adoption of other agroecological practices could be attributed to insufficient advisory support or inadequate training of extension agents in agroecology.

Perceptions of Environmental and Health Risks

The perception of environmental and health risks plays a significant role in the adoption of agroecological practices as well. Farmers who are aware of the environmental and health hazards associated with intensive agricultural practices are more likely to adopt measures such as permanent soil cover, resistant crop varieties, the introduction of beneficial organisms, and alternative methods to chemical fertilizers. These findings align with previous studies in literature. For instance, Läpple (2010), Genius et al. (2006), and Burton et al. (2003) all demonstrated that farmers with a heightened environmental concern are more inclined to transition toward sustainable agricultural practices. Their research highlights a consistent trend: the stronger the environmental awareness among farmers, the higher their likelihood of adopting practices that promote ecological balance and sustainability. On a more individual level, the perception of health risks has emerged as a critical factor in influencing the transition to sustainable farming, particularly among groups of farmers who were initially resistant to adopting such practices. Bellon and Lamine (2008) observed that health-related concerns could act as a catalyst for change, encouraging these farmers to adopt agroecological approaches even when environmental considerations alone were insufficient to prompt a conversion.

Access to Credit

Access to credit plays a positive role in the adoption of crop rotation and intercropping practices by enabling farmers to acquire the necessary inputs. According to Sale et al. (2014), access to credit is a key factor in shaping agricultural strategies, as farmers with easier access to financial resources are more likely to adopt new technologies. Similarly, Ouédraogo et al. (2010) and Mbétid-Bessane (2014) emphasize the importance of credit as a potential determinant of farmers' behavior toward innovation. Credit alleviates financial barriers that might otherwise hinder the adoption of such practices. However, the limited adoption of other agroecological practices can be attributed to farmers' lack of access to formal agricultural credit from relevant institutions. Instead, they often rely on supplier or family-based credit. These informal credit sources typically involve smaller sums that are insufficient to cover the substantial investments required for other agroecological practices, such as acquiring specialized inputs and equipment. Consequently, practices that demand higher financial investments remain less adopted due to these constraints.

Seed Autonomy and Plant Nurseries

Lastly, the availability of a plant nursery within a farm has a positive impact on the use of local seeds, as it enables farmers to cultivate high-quality plants adapted to the local environment while fostering their autonomy. A plant nursery allows farmers to better control seedling production, ensuring that the crops are more resilient and suited to the specific conditions of their region. Farmers frequently cite the lack of local seed varieties as a major challenge, emphasizing that the hybrid seeds they rely on are often poorly adapted to local conditions. Although these imported varieties are marketed as resistant, they rarely perform as expected because they are not inherently local. This mismatch underscores the limitations of relying on external inputs, which can lead to reduced agricultural performance and dependency.

Constraints to the adoption of agroecological practices

A range of challenges continue to hinder the development and adoption of agroecological practices, from economic challenges to systemic market obstacles, making the transition to sustainable farming increasingly difficult.

Economically, the low return on investment associated with agroecology remains a critical barrier. This challenge is further compounded by the lack of government support to incentivize these practices, leaving farmers without adequate encouragement to make the shift.

Moreover, the absence of agricultural insurance and the difficulties in accessing formal credit systems create substantial challenges, particularly for those seeking to invest in agroecological transitions.

Market-related obstacles intensify these challenges, On the supply side, farmers face difficulties in accessing essential inputs such as locally adapted seeds and resistant crop varieties. On the demand side, the lack of dedicated markets for agroecological products creates financial uncertainty exposing farmers to financial risks and resulting in reduced profitability.

Land ownership insecurity adds another layer of complexity. Tenant farmers, who often lack ownership rights, are especially reluctant to adopt agroecological practices. The uncertainties surrounding land tenure discourage long-term investments in sustainable techniques, perpetuating a cycle of short-term decision-making.

Additionally, knowledge and capacity gaps remain major obstacles. Many farmers lack familiarity with agroecological methods, particularly in specialized areas like biological pest control. This knowledge deficit is compounded by the absence of guidance and support from agricultural institutions, leaving farmers without the necessary training and resources to implement these practices effectively. Labor shortages, especially of skilled agricultural workers, compound these challenges, as many agroecological techniques require significant expertise and effort.

Finally, the lack of access to appropriate infrastructure and equipment, such as multi-span greenhouses, limits the ability of farmers to innovate and optimize their practices.

Without the necessary tools and facilities, it becomes difficult to create an environment conducive to sustainable and innovative farming practices.

CONCLUSION

The analysis highlights that agroecological practices are adopted by vegetable producers in the commune of Bou Ismaïl, although the level of adoption varies from one farm to another. Several factors influence this adoption, which can be either internal, such as the characteristics of the farmer and the farm, or external, including economic, political, and environmental aspects. These factors shape adoption decisions through a diverse range of motivations that go beyond purely economic considerations. Despite this, the development of agroecological practices faces several constraints, including financial limitations, knowledge gaps, and insufficient institutional support.

Agroecological practices are beneficial for both consumer health and environmental sustainability, but addressing the challenges to their adoption requires a multifaceted approach. Agricultural extension services should organize regular training sessions on the benefits of these practices in collaboration with local experts and agricultural research institutions. Raising consumer awareness about the advantages of agroecological practices is equally important to ensure sustained demand. In addition, facilitating access to locally adapted seeds, efficient irrigation equipment, and organic soil amendments is essential in supporting farmers through this transition and local cooperatives and agricultural organizations can play a key role in providing these resources. Furthermore, implementing financial and fiscal incentives, such as subsidies for purchasing suitable equipment or preferential loans for agroecological investments, can encourage wider adoption. Creating a dedicated market for agroecological

products is also necessary to ensure fair remuneration for farmers. This could be accomplished through certification or labeling initiatives that highlight the unique value of these products and connect them directly to informed consumers.

This study, while it contributes to literature by shifting the focus from consumers to producers, addressing a perspective often overlooked in existing research, has certain limitations. It was conducted on a small sample size and focused exclusively on intensive vegetable production, which limits its generalizability. The factors influencing adoption can vary significantly across different agricultural contexts, such as climate, farm structure, and downstream markets, as well as between types of production and in different regional or temporal settings. These variations, combined with the influence of agricultural, economic, and political factors, mean that the findings may not be directly transferable to other regions or periods. Additionally, the explanatory models used in this study, such as the logit model, did not account for spatial dependence which can have a significant impact on decision-making. Future research addressing these limitations could provide a more comprehensive understanding of the factors driving the adoption of agroecological practices.

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