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Identifying population profiles and estimating the likelihood of adopting vermicomposting using machine learning methods

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ABSTRACT

Objective: This study aims to identify the profiles of households that are most likely to adopt vermicomposting.

Methodology and Results: Through a survey of 278 households in the localities of Bama, Bobo-Dioulasso and Kotédougou in Burkina Faso, it highlights disparities in waste management and recovery according to the level of urbanisation. Sorting of waste is the most widespread practice, with 25 to 38 per cent of respondents, followed by composting waste, with 19 to 27 per cent. Vermicomposting is virtually non-existent, ranging from 0 to 4%. The Random Forest model with mtry = 7 achieves an accuracy of 77.45% and a kappa of 0.65. The change in composting practice is the most decisive variable with a Gini index of 18, followed by waste management at 13, and age and household size at 11. The decision tree revealed that 35% of households, with highly motivated and educated profiles, involved in various waste management practices, have the highest adoption probabilities, ranging from 0.62 to 0.75. Vermicomposting has an elitist adoption profile, almost exclusively associated with academics and civil servants, which explains its low uptake.

The findings highlight the need to promote vermicomposting through awareness campaigns and practical training. Local authorities and extension services should prioritize motivated household profiles and provide them with the technical support and materials needed to get started. These measures could encourage wider adoption of vermicomposting and improve the recovery of household organic waste in Burkina Faso.

Keywords: vermicomposting, adoption, Random Forest, decision tree, waste.

INTRODUCTION

Organic waste management is a major environmental and health challenge in developing countries, where rapid urbanization and population growth are putting increasing pressure on waste collection and treatment systems (Guerrero *et al.,* 2013; Hoornweg & Bhada-Tata, 2012). In sub-Saharan Africa, this problem is particularly acute in peri-urban and rural areas, where waste management infrastructure remains inadequate or non-existent (Manga *et al.,* 2008; Ogawa, 2005). Faced with this challenge, the recovery of organic waste by techniques such as composting and vermicomposting appears to be a promising solution, allowing not only to reduce the volume of waste, but also to produce quality organic amendments for agriculture (Lim *et al.,* 2016; Nigussie *et al.,* 2016). Vermicomposting, a process of decomposing organic matter through the combined action of earthworms and microorganisms, has significant advantages over traditional composting, including faster humus production, better nutritional quality of the final product and reduced greenhouse gas emissions (Edwards *et al.,* 2011; Domínguez & Edwards, 2011; Lim *et al.,* 2015). Studies have shown that vermicompost improves soil fertility, water retention and crop yields while reducing dependence on chemical inputs (Arancon *et al.,* 2006; Lazcano *et al.,* 2008). Despite these proven benefits in many contexts, the uptake of this technique remains limited in developing countries, where traditional waste management practices, such as landfilling, incineration or piling, still predominate (Singh *et al.,* 2011; Munroe, 2007). Several studies have documented barriers to the adoption of innovative agricultural technologies, highlighting the importance of socio-economic, cultural and educational factors in household decision-making processes (Rogers, 2003; Knowler & Bradshaw, 2007). In Burkina Faso, a Sahelian country facing considerable agricultural and environmental challenges, the issue of organic waste management and recovery is part of a broader issue of food security and the resilience of agrarian systems (Zougmoré *et al.,* 2014; Thiombiano & Meshack, 2009). Soil degradation, erosion and low organic matter content are major constraints to agricultural productivity in this region (Bationo *et al.,* 2007). While sorting and composting are the subject of local initiatives in some regions (Kientga, 2006; Compaoré *et al.,* 2010), vermicomposting remains a marginal practice, poorly documented and unevenly disseminated in the territory. The determinants of its adoption, the socio-demographic profiles of potential adopters and the specific obstacles to its dissemination remain poorly understood, thus limiting the effectiveness of public policies and awareness programs aimed at promoting this technique (Mando *et al.,* 2005). This study aims to fill this gap by identifying factors influencing the potential adoption of vermicomposting in three localities in the Guiriko region of Burkina Faso: Bama, Bobo-Dioulasso and Kotédougou. It also aims to predict the probabilities of adoption of vermicomposting based on socio-economic, behavioral and attitudinal variables. By mobilizing a methodological approach combining multivariate statistical analyses, multiple component analysis (MCA) and modeling by Random Forest (Breiman, 2001; Cutler *et al.,* 2007), this research makes it possible to establish a typology of potential adopters and to identify priority action levers to promote the spread of vermicomposting in these areas. The results of this study make significant contributions to the literature on the adoption of agricultural innovations in Sahelian contexts, documenting for the first time the specific determinants of vermicomposting in Burkina Faso and proposing a predictive analysis methodology applicable to other environmental technologies. The use of machine learning to predict the adoption of agricultural innovations represents an innovative approach in the West African context (Elavarasan & Vincent, 2020; Liakos *et al.,* 2018). At the practical level, they provide policy makers, non-governmental organizations and rural development actors with essential information to design programs to promote vermicomposting adapted to local realities and targeting the populations most receptive to this innovation.

MATERIALS AND METHODS

Study area: The study was conducted in three localities in the Guiriko region of Burkina Faso: Bama, Bobo-Dioulasso and Kotédougou. This region, located in the southwestern part of the country, is characterized by a Sudano-Sahelian climate with an average annual rainfall ranging between 900 and 1200 mm (Guinko and Fontès, 1985). The Guiriko region is an important agricultural area in Burkina Faso, with a predominantly rural population practicing subsistence agriculture and livestock farming (INSD, 2019). Bobo-Dioulasso, the capital of the region, is the second largest city in the country with an estimated population of more than 984,603 (RGPH, 2019). It is an important urban center characterized by a high population density and diversified economic activities (trade, crafts, services). Bama and Kotédougou are peri-urban and rural localities located respectively about 30 km and 22 km from Bobo-Dioulasso. These areas have contrasting socio-economic characteristics, with a predominance of agro-pastoral activities. The choice of these three localities is based on their complementarity in terms of urbanization gradient and diversity of agricultural production systems, which makes it possible to understand the variability of organic waste management practices in differentiated socio-economic contexts.

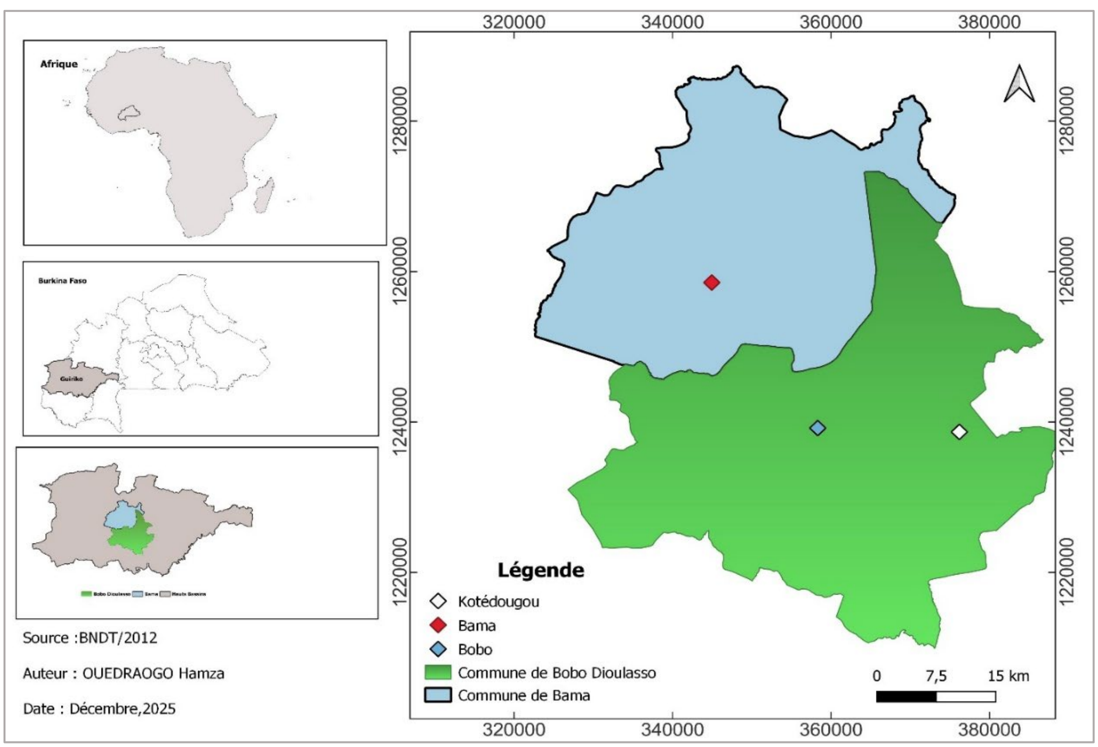


Figure 1: Location map of Bama, Bobo-Dioulasso and Kotédougou

Sampling and data collection

Sampling Plan: Stratified sampling was implemented to ensure balanced household coverage in the different localities studied. Each locality was considered a separate stratum. As a first step, neighbourhoods for urban areas and villages for rural areas were identified with the support of local authorities and community leaders. Within each neighbourhood or village, households were selected according to a spatial-based reasoned method. The investigators systematically surveyed inhabited areas along the main and secondary axes, making sure to survey households spread throughout the territory in order to avoid excessive concentration in the same area. When the approached household was unavailable or refused to participate, the immediate neighbouring household was solicited. This procedure has made it possible to maintain the continuity of the route while guaranteeing the achievement of the number of staff planned per zone. A total of 278 households were surveyed, including 89 in Bama, 136 in Bobo-Dioulasso and 53 in Kotédougou. The distribution of households between localities took into account their demographic importance and their accessibility on the ground. Although this approach is not based on a strict probabilistic drawing, it has made it possible to cover the spatial and socio-demographic diversity of households.

Data collection Tool: Data were collected through a structured, face-to-face questionnaire administered to heads of households or their representatives. The questionnaire, prepared in French and translated into local languages (Dioula, Moore), included several sections:

- socio-demographic characteristics: age, sex, level of education (out of school, primary, secondary, medersa, university), marital status (single, married), occupation (farmer/breeder, trader, craftsman, civil servant, unemployed, retired), household size, place of residence;
- current waste management practices: household waste management methods (landfill, incineration, domestic stacking, waste disposal), sorting practices, composting and vermicomposting;
- knowledge and perceptions: knowledge of organic waste recovery techniques, perceived benefits of sorting and composting, barriers to adoption;
- attitudes and behavioural intentions: willingness to adopt sorting, composting and vermicomposting, willingness to receive training on these techniques, willingness to change current composting practices.

The questionnaire was pre-tested with 5 households, which allowed the formulation of the questions to be adjusted and the clarity of the measurement instrument to be improved.

Collection period and conditions: Surveys were conducted between January and February 2024 during the dry season, in order to find the heads of households at home. For the same reasons, the surveys were carried out on weekends in Bobo-Dioulasso. Each interview lasted an average of 45 to 60 minutes. Informed consent was obtained from participants prior to each survey, in accordance with the ethical principles of social science research.

Study Variables

Dependent Variables: The main dependent variable of this study is the probability of adoption of vermicomposting, estimated from the predictive model Random Forest. This continuous variable, between 0 and 1, reflects a household's propensity to adopt the technique of vermicomposting according to its socio-economic characteristics and declared attitudes. Three secondary binary variables were also considered: the current practice of sorting (0 = no, 1 = yes), the current practice of composting (0 = no, 1 = yes) and the current practice of vermicomposting (0 = no, 1 = yes).

Independent Variables: The explanatory variables used in this study can be grouped into four categories:

- socio-demographic variables: age (continuous variable in years), sex (binary variable: 0 = woman, 1 = man), educational attainment (categorical variable: out of school, primary, secondary, medersa, university), marital status (binary variable: 0 = single, 1 = married), occupation (categorical variable: farmer/herder, trader, craftsman, civil servant, unemployed, retired, housewife), household size (continuous variable), locality (categorical variable: Bama, Bobo-Dioulasso, Kotédougou);
- variables related to waste management practices: type of waste produced, current waste management methods (landfill, incineration, pile-up, waste disposal), sorting practices, composting and vermicomposting, etc.;
- attitudinal and behavioural variables: dis

Data Analysis

Descriptive and comparative statistical analyses: Statistical analyses were performed using R version 4.5.1 software. Descriptive statistics (averages, standard deviations, frequencies and proportions) were used to characterize the sample and describe waste management practices in the three localities. Comparison of the proportions of households engaged in sorting, composting and vermicomposting was made using the Pearson Chi-Deux test. Mean readiness to adopt these techniques and training readiness scores were compared between localities by variance analyses, followed by post-hoc Tukey tests. The materiality threshold was set at 0.05.

Multiple Component Analysis: Multiple Component Analysis (MCA) was conducted to identify socio-demographic profiles associated with sorting, composting and vermicomposting practices. This method, adapted to qualitative variables, has made it possible to visualize the associations between practices and socio-demographic characteristics. Three distinct MCAs were performed, successively considering each of the practices as a variable of interest. Socio-demographic variables were integrated as active variables. The interpretation of the results was based on the contributions of the modalities to the axes and their quality of representation. The analyses were conducted with the FactoMineR package and the graphics produced with factoextra.

Modelling by Random Forest: The Random Forest model was used to analyse the determinants of the uptake of vermicomposting. This method was chosen because of its ability to manage heterogeneous variables and complex relationships between explanatory factors. Data were divided into a training set (70%) and a test set (30%). Several model configurations were evaluated by varying the mtry parameter, with 500 trees and 10-ply cross validation. Performance was assessed using accuracy and the kappa coefficient. The model with the best performance was selected. The importance of the explanatory variables was evaluated from the Mean Decrease Gini index.

Decision Tree: A decision tree of the CART type was constructed in order to identify profiles of potential adopters of vermicomposting. Pruning was carried out to limit over-learning, by retaining the level of complexity minimizing the cross-validation error. The classes obtained were characterized according to their mean probabilities of adoption and the discriminating variables.

Analysis of decision-making coherence: An inconsistency score was calculated to assess the consistency between reported attitudes and actual practices. The relationship between this score and the probability of adoption predicted by the Random Forest model was analysed using a simple linear regression, in order to examine the role of decision coherence in the adoption of vermicomposting.

RESULTS

Sorting, composting and vermicomposting practices in the three localities: Waste recovery practices in Bama, Bobo and Kotédougou localities are sorting, composting and vermicomposting (Figure 2). Sorting is the most common practice in all localities, with 38.2 per cent in Bama, 25.7 per cent in Bobo and 32.7 per cent in Kotédougou respectively. Although the highest proportion is observed in Bama, differences between localities are not statistically significant ($p = 0.4545$). As regards composting, the proportions observed in Bama and Bobo are identical, i.e. 19.1% each, while Kotédougou has a slightly higher value with 26.9%. However, this variation also remains insignificant ($p=0.1362$), which means that the practice of composting is identical between the zones. Vermicomposting is very little practiced in the three localities, with very low proportions, respectively 2.2% in Bama, 3.7% in Bobo and 0% in Kotédougou. The absence of significant difference ($p = 0.4718$) reflects a low adoption of this technique in the region studied.

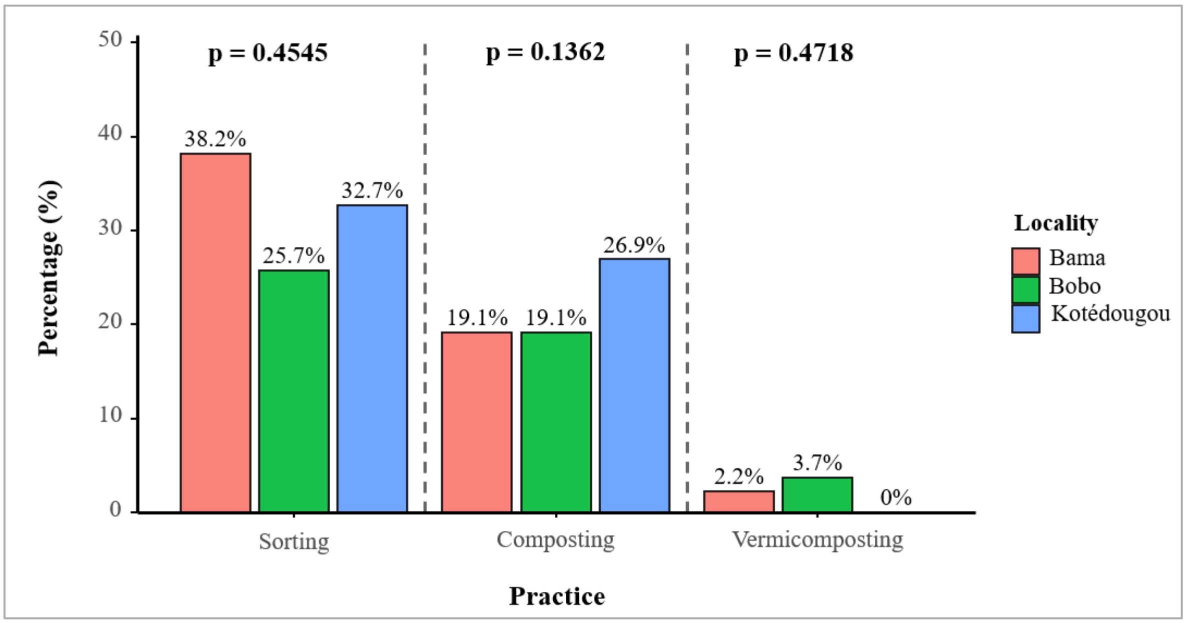


Figure 2: Sorting, composting and vermicomposting by location

Willingness to adopt sorting, composting and vermicomposting by locality: Comparative analysis of the willingness to adopt sorting, composting or vermicomposting in the localities of Bama, Bobo and Kotédougou revealed highly significant differences, with a p-value of 2.35E-30 (Figure 3). Regarding composting, Kotédougou stands out with a high average score of 2.9. Bama holds an intermediate position with a score of 2.3, while Bobo, with a score of 1.3, shows a reluctance. On the other hand, waste sorting has an opposite configuration. Bobo has the highest average score of 2.7, which reflects a strong propensity for this practice. Kotédougou follows with a score of 2.5 then Bama with a value of 2.4. With regard to vermicomposting, the trend is similar to that observed for composting. Kotédougou again had the highest score at 2.6. Bama, with a score of 2.3, is also receptive, while Bobo remains the least disposed with a score of 1.9. Overall, Kotédougou appears to be the most favourable locality for waste recovery practices by composting and vermicomposting, while Bobo is more oriented towards sorting.

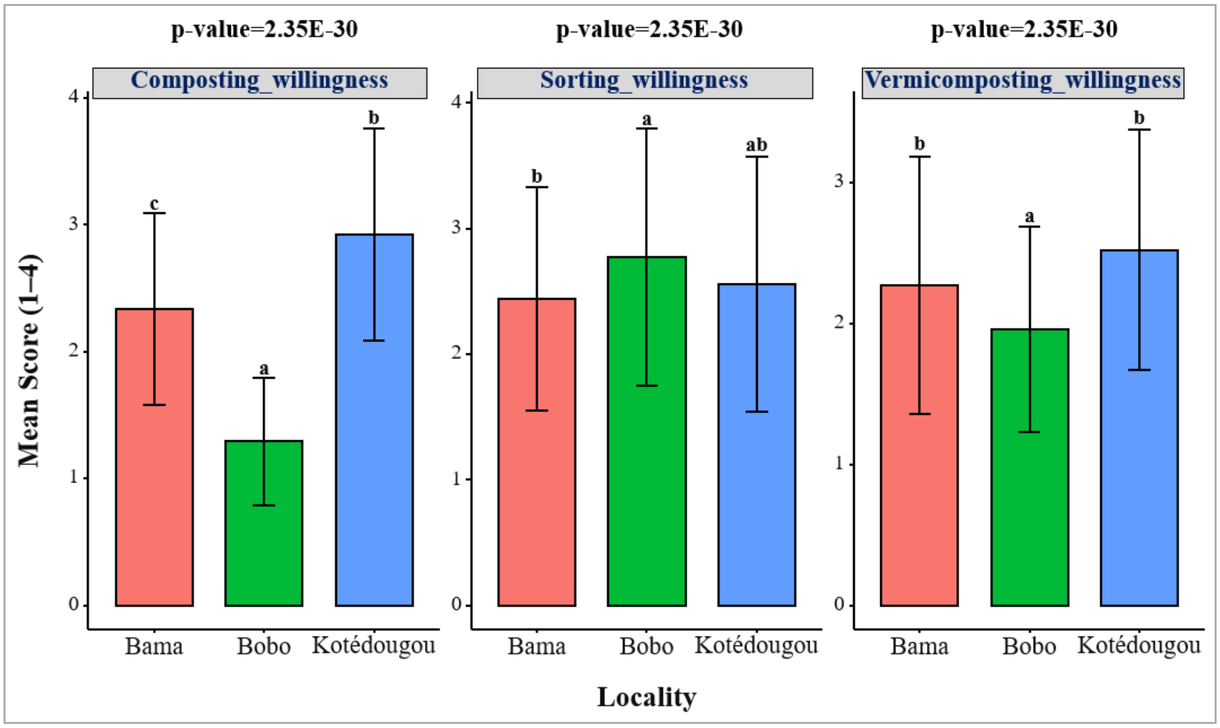


Figure 3: Willingness to adopt sorting, composting and vermicomposting by locality

Willingness to train in sorting, composting and vermicomposting according to localities: Comparative analysis of willingness to be trained for composting, sorting and vermicomposting in the localities of Bama, Bobo and Kotédougou revealed statistically significant differences (Figure 4). For composting, the differences observed are very highly significant, with a p-value of 1.91e-31. Kotédougou had the highest average score of 4.0. Bama has an intermediate score of 3.6, while Bobo, with a score of 1.9, has a low disposition for composting training. In terms of willingness to be trained in waste sorting, the differences are also significant with a p-value of 0.00281. Kotédougou maintained its predominance with a score of 3.7, while Bama and Bobo posted close values, respectively 3.2 and 3.1. For vermicomposting, the differences remain highly significant, with a p-value of 6.1e-7. Kotédougou still has the highest score, 3.4, followed by Bama with a score of 3.1, while Bobo remains behind with a score of 2.4. Overall, Kotédougou stands out as the locality with the most willingness to be trained for all these practices.

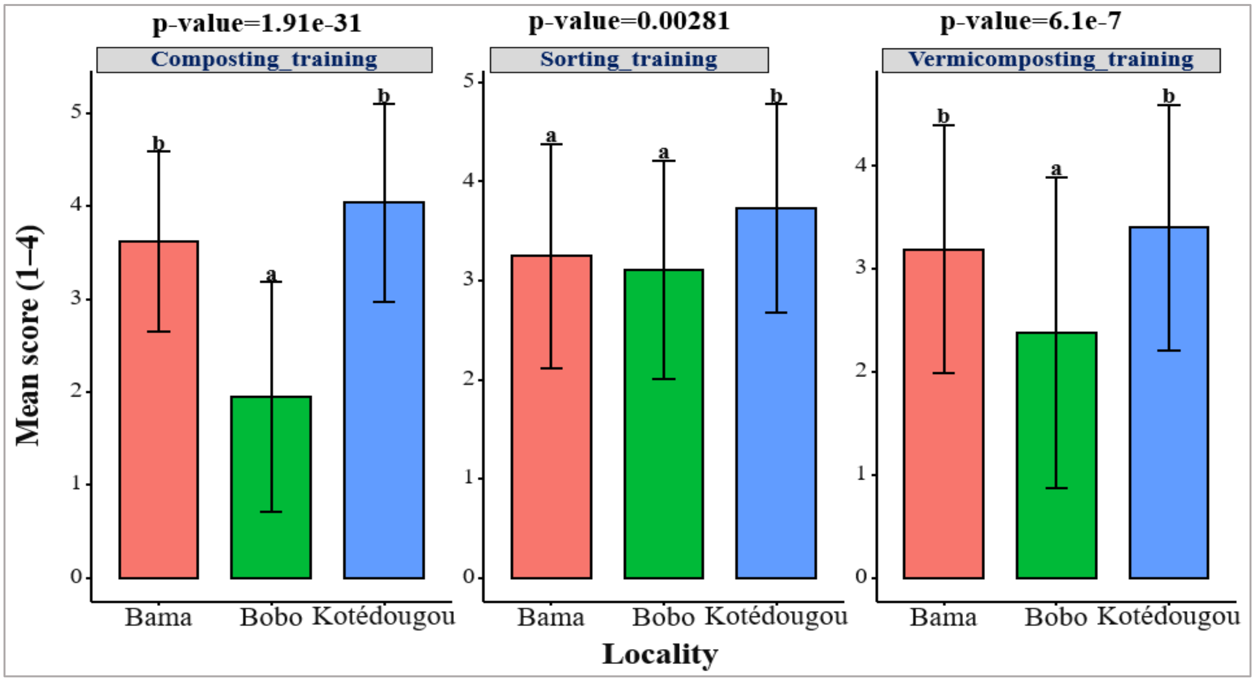
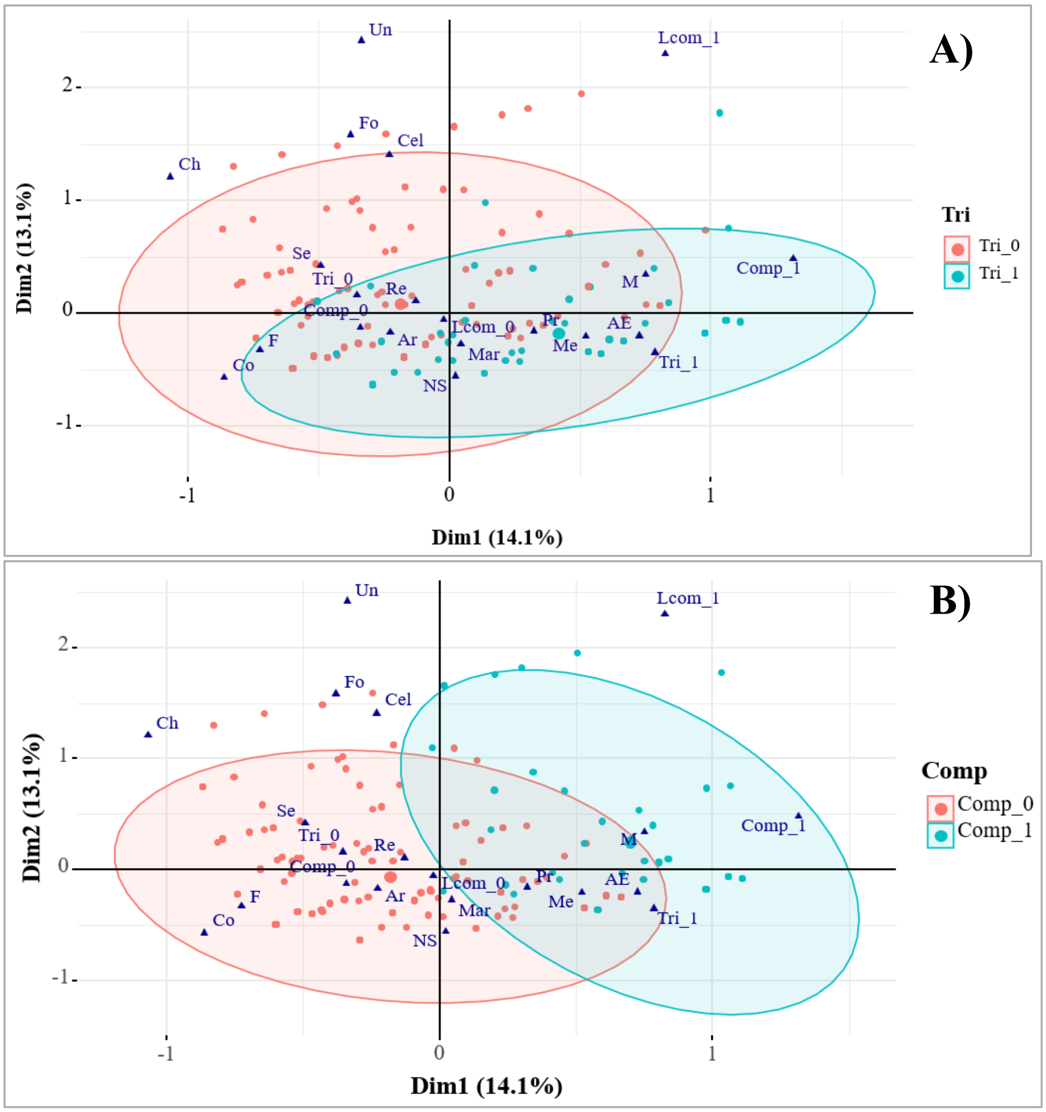
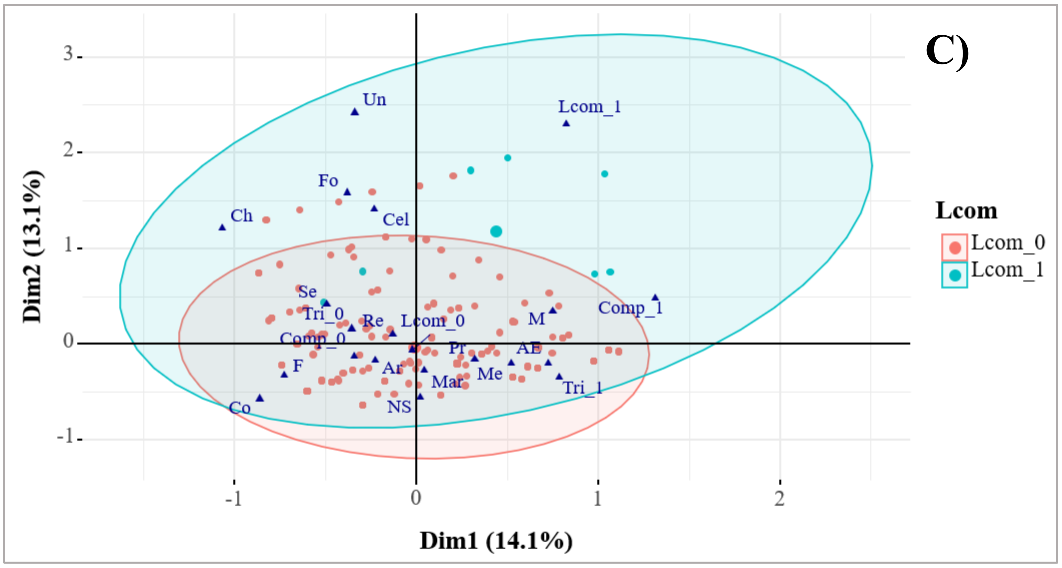


Figure 4: Willingness to receive training in sorting, composting and vermicomposting

Profiles of respondents related to sorting, composting and vermicomposting practices: The analysis of multiple matches revealed distinct socio-demographic profiles that were prioritized according to the organic waste management practices adopted by the respondents (Figure 5). The three graphs illustrate how sorting, composting and vermicomposting mobilize differentiated social determinants. The two dimensions total 27.2% of the inertia, i.e. 14.1% for dimension 1 (Dim1) and 13.1% for dimension 2 (Dim2). Concerning the sorting of waste (first figure), dimension 1 makes a distinction between practitioners (Sorting_1) and non-practitioners (Sorting_0). The individuals who practice sorting are mainly positioned in the positive zone of the horizontal axis, in association with profiles characterized by a high school and professional capital. These are academics (One), singles (Cel) and civil servants (Fo) who constitute the core of practitioners. Conversely, the non-practitioners (Tri_0) are concentrated in the negative space of the axis, strongly correlated with the unemployed and low-school-level categories: the unemployed (Ch), the out-of-school (NS), the retired (Re) and the individuals of secondary level (Se). Traders (Co), women (F) and craftsmen (Ar) are also on the side of non-practitioners. For composting (second figure), the analysis shows a substantially different and more diversified configuration. Composting practitioners (Comp_1) gather in the positive zone of axis 1, in proximity with men (M), married people (Mar) and especially farmers / breeders (AE). Non-practitioners (Comp_0) nevertheless remain strongly linked to profiles with little or no schooling (NS, Pr), women (F), craftsmen (Ar) and traders (Co). Civil servants (Fo), singles (Cel) and academics (Un) are in an intermediate zone. Vermicomposting (third figure) has the most elitist and segmented profile of the three practices studied. Dimension 2 (13.1%) reveals a particularly marked segmentation: the practitioners of vermicomposting (Lcom_1) are concentrated in the upper right zone of the graph, in almost exclusive association with academics (One) and, to a lesser extent, with singles (Cel) and civil servants (Fo). Non-practitioners (Lcom_0), on the other hand, are widely dispersed in the factorial space, occupying all the socio-demographic categories that are the unemployed (Ch), traders (Co), housewives (F), craftsmen (Ar), the out-of-school (NS), the primary (Pr) and secondary (Se) levels, pensioners (Re), but also individuals at the medersa level (Me) and the married (Mar).





Waste sorting performed (Sorting_1), waste sorting not performed (Sorting_0), composting performed (Comp_1), composting not performed (Comp_0), vermicomposting performed (Lcom_1), vermicomposting not performed (Lcom_0), academic (One), single (Cel), civil servant (Fo), unemployed (Ch), trader (Co), housewife (F), artisan (Ar), not enrolled (Ns), primary (Pr), secondary (Se), medersa (Me), married (Mar), retired (Re), farmer/breeder (AE) and man (M). Multi-component analysis with sorting (A), composting (B) and vermicomposting (C) as variables of interest

Figure 5: MCA of sorting, composting and vermicomposting practices by socio-demographic profile

Identification of the best Random forest model according to the mtry parameter: Random Forest analysis with different mtry values reveals satisfactory overall performance, with significant variations depending on the chosen configuration (Table I). The optimal model corresponds to mtry = 7, reaching an accuracy of 77.45% and a kappa of 0.65, which shows a substantial agreement between the predictions and the real observations. This performance is significantly higher than the other configurations tested, with a standard deviation of 0.09 indicating good stability of the model. The results show a progressive and significant decrease in performance when the number of variables considered at each division decreases. The accuracy increases from 77.45% for mtry = 7 to only 64.39% for mtry = 3, demonstrating the importance of exploring a sufficient number of variables to understand the relationships between the data. The intermediate configurations (mtry=8, 6, 4 and 3) display accuracies of between 63.39% and 69.95%, with kappa values varying from 0.48 to 0.53.

Table 1: Comparative Analysis of Predictive Performance of Random Forest

Model	SE	Nb_variable	mtry	Accuracy_pct	Kappa_round	AccuracySD
Change_composting, Vermicomposting_willingness_adj, Choise, Sorting_advantage, Profession, Training_composting, Practice_sorting, Incoherence_vermicomposting, Practice_vermicomposting, Waste_amendement						
RF_mtry_7	0.0908	7	7	77.45	0.6469	0.09076341
Change_composting, Vermicomposting_willingness_adj, Choise, Sorting_advantage, Profession, Practice_sorting, Waste_type, Practice_vermicomposting, Sorting_willingness, Sorting						
RF_mtry_8	0.0817	8	8	69.95	0.5256	0.08172690
Change_composting, Vermicomposting_willingness_adj, Choise, Practice_sorting, Sorting_advantage, Score_incoherence, Incoherence_vermicomposting, Profession, Sorting_willingness, Sorting						
RF_mtry_3	0.0757	3	3	64.39	0.4985	0.07565300
Change_composting, Vermicomposting_willingness_adj, Profession, Practice_sorting, Choise, Incoherence_vermicomposting, Sorting_advantage, Waste_type, Sorting, Practice_vermicomposting						
RF_mtry_6	0.1049	6	6	63.87	0.4945	0.10493406
Change_composting, Vermicomposting_willingness_adj, Practice_sorting, Sorting_advantage, Choise, Sorting_willingness, Waste_type, Incoherence_vermicomposting, Score_incoherence, Profession						
RF_mtry_4	0.0983	4	4	63.39	0.4861	0.09831960

Variables identified by the Random Forest model in predicting the adoption of vermicomposting: The application of Random Forest to the different variables involved in the study showed the importance of each of them in the model (Figure 6). The main factor influencing the adoption of vermicomposting is the change in composting practice, with an importance of 18. Waste management, age and household size also play a significant role, with respective importance close to 13 and 11. The profession and the training received in composting and vermicomposting, with values close to 10 and 9, also contribute. Variables such as the willingness to compost, the type of waste produced and sorting training have intermediate importance, between 7 and 8, while sorting habits, the level of study and the willingness to change these practices vary between 6 and 7. Other factors, such as locality, individual choices and willingness to engage in vermicomposting, have a lower weight of about 5, and current composting practices, consistency of responses, gender, residence and socio-economic status appear to contribute little, less than 4.

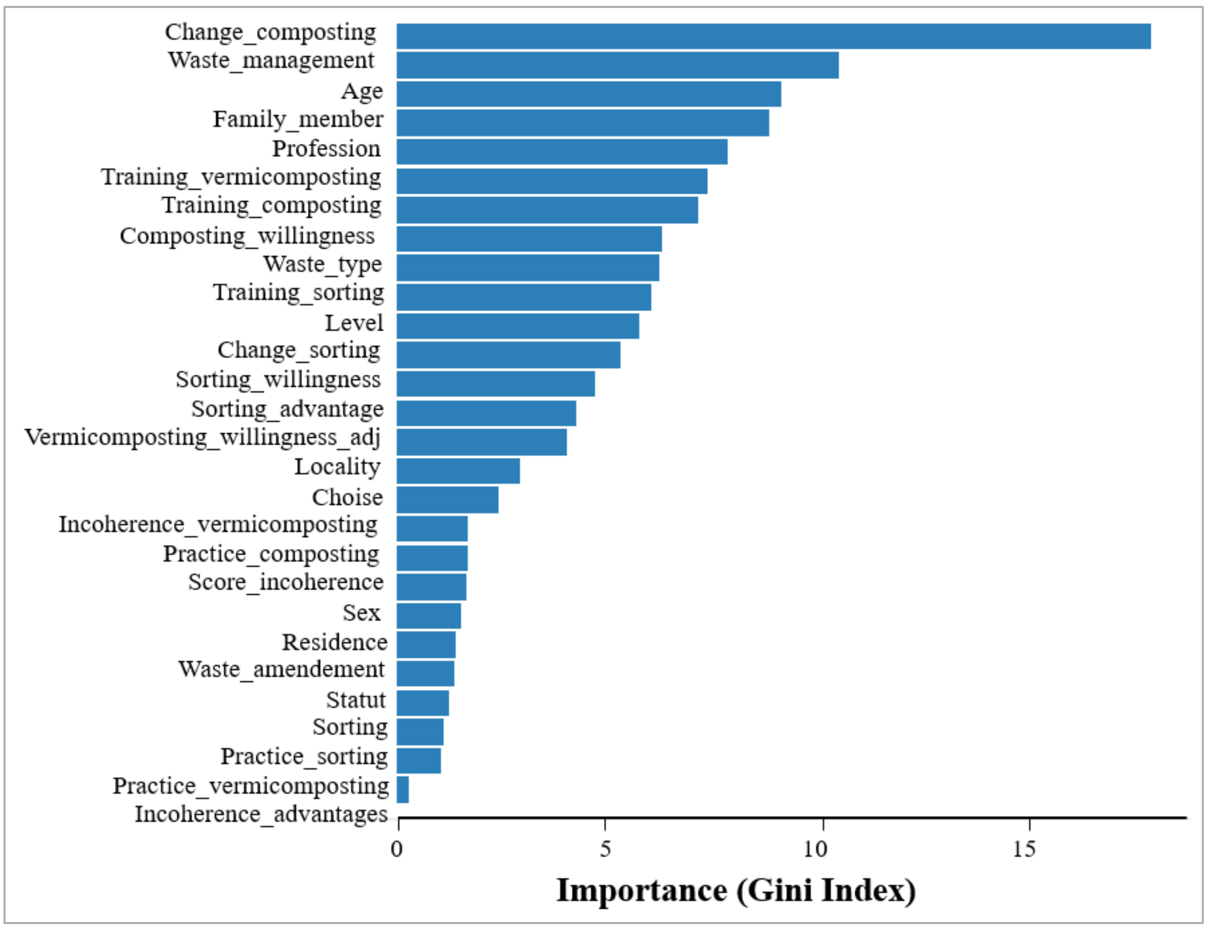
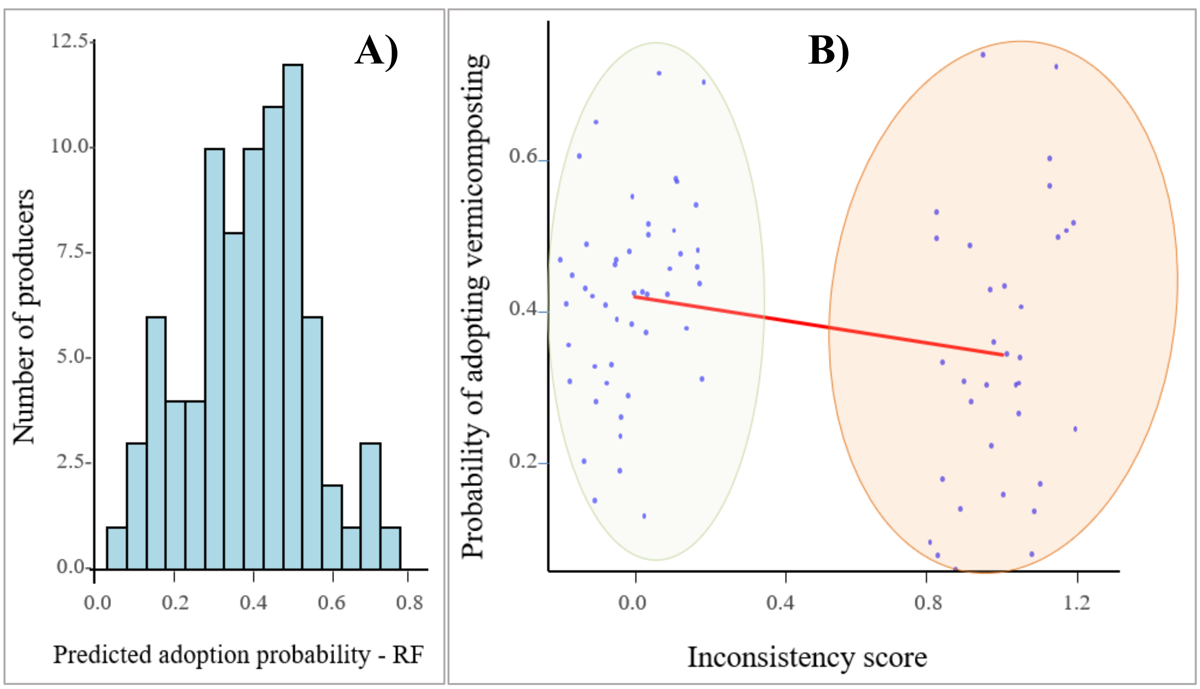


Figure 6: Importance of variables in predicting the adoption of vermicomposting according to the Random Forest model

Distribution of the probabilities of adoption of vermicomposting and influence of decision coherence according to the Random Forest model: The Random Forest model was used to obtain the probability of adopting vermicomposting from the observed characteristics and the consistency of the respondents' responses (Figure 7). The distribution of these probabilities according to the number of respondents revealed a strong heterogeneity within the sample. The values range from 0.05 to 0.75, with a concentration around 0.30–0.55. Most producers are therefore in an intermediate zone, reflecting a moderate sensitivity to innovation rather than a clear commitment to or against its adoption. This dispersion reflects the diversity of socio-economic profiles and attitudes identified in the field. The response inconsistency score also has an influence on the likelihood of future adoption of vermicomposting. A decreasing trend is evident: producers with the highest levels of inconsistency have lower probabilities of adoption. The adjusted straight line confirms this negative relationship. She suggests that a stable and coherent discourse favours openness to innovation, while a more unstable positioning is associated with a lower interest in vermicomposting. This result supports the idea that decision-making coherence plays a role in the technological choices of agricultural households.



Distribution of probabilities by number of respondents (A) and consistency of responses (B)
Figure 7: Predicting the Likelihood of Adoption of Vermicomposting

Probabilities of adoption of vermicomposting according to profiles: The decision tree highlights four classes of adoption of vermicomposting (Figure 8). The highly unlikely class (1) comprises between 3 and 9% of households, mainly farmers, traders or craftsmen, who have a low interest in vermicomposting and training in sorting and/or composting. They are also little involved in waste management. Their average probability of adoption ranged from 0.04 to 0.29. The low probability class (2), which is broader with 5-12% of households, includes individuals with a slightly higher interest in innovation and moderate experience in waste sorting and management practices, with probabilities of adoption ranging from 0.20 to 0.50. The probable class (3), representing 4-6% of the sample, includes more committed households with a strong interest in sorting and composting training, as well as domestic waste management, including domestic waste heaping and waste disposal. In these groups, the probabilities of adoption exceed 0.60. The highly probable class (4), with 35% of households, brings together highly motivated and educated profiles involved in various waste management practices such as landfilling, incineration and waste disposal. The odds of adoption are highest, ranging from 0.62 to 0.75, which is the maximum level observed in the study.

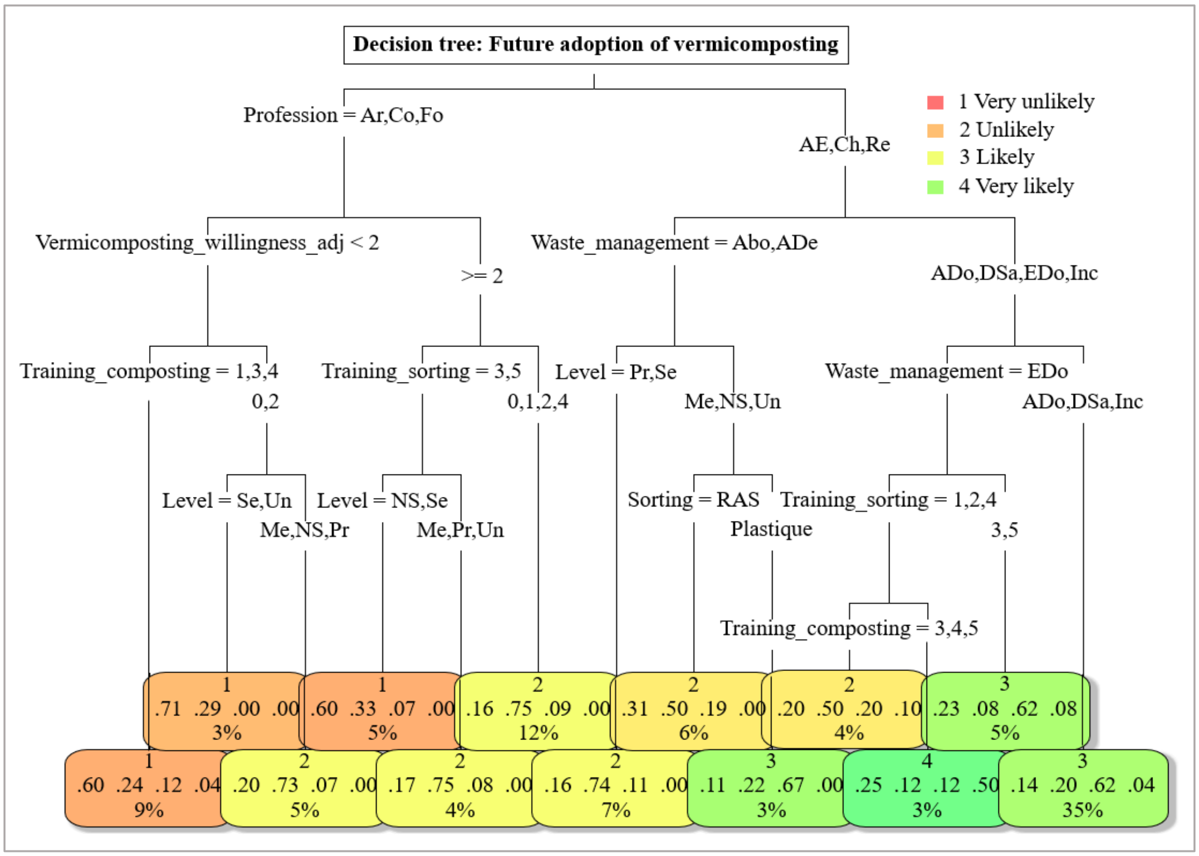


Figure 8: Decision tree of factors influencing the adoption of vermicomposting

DISCUSSION

Waste management patterns and determinants of household preferences: The preponderance of the locality as an explanatory factor of the modes of management underlines the weight of infrastructure and local public policies. The existence of a subscription system exclusively for Bobo-Dioulasso illustrates this reality. (Guerrero *et al.,* 2013), in their review on solid waste management in developing countries, highlighted that access to formal collection services depends primarily on the institutional capacity of municipalities rather than on individual household characteristics. The coexistence of formal and informal practices in Bobo-Dioulasso, in contrast to the almost exclusive domination of informal practices in rural areas, confirms the observations of (Manga *et al.,* 2011) in Cameroon. These authors have demonstrated that sub-Saharan African secondary cities are characterized by a fragmentation of management systems, creating a mosaic of solutions adapted to different neighbourhoods and socio-economic groups. This diversity, far from being a dysfunction, often represents a pragmatic adaptation to budgetary constraints and realities on the ground. The practice of vermicomposting is low in all the localities studied. Studies conducted by (Rastegari *et al.,* 2023) have shown that this practice, although technically accessible, often encounters cultural barriers and a lack of knowledge of its benefits. The complete absence of this practice in Kotédougou suggests that geographical distance and relative isolation can constitute barriers to the diffusion of innovations, even in potentially receptive communities. This observation is consistent with the findings of (Rogers, 2003) on the dissemination of innovations, which underscores the importance of communication networks and accessibility to information sources in the adoption of new practices. The enthusiasm for composting with free removal and remuneration in Kotédougou and Bama, compared to the preference for sorting in Bobo-Dioulasso, reveals distinct economic and cultural rationalities. In rural areas, where agriculture is the dominant activity, the direct recovery of organic waste meets an immediate need to improve soil fertility. This utilitarian logic has been documented by (Cofie *et al.,* 2006) in Ghana, which have shown that the acceptance of organic valorisation techniques is strongly correlated with the perception of tangible agronomic benefits. Conversely, in urban contexts such as Bobo-Dioulasso, where the relationship with agriculture is more remote, sorting appears to be a more coherent solution with an urban lifestyle and delegated waste management. In addition, cities are faced with a problem of space for composting, especially in a context where the majority of the population lives in rented yards. According to (Nigussie *et al.,* 2015), agricultural communities have an intuitive understanding of organic matter cycles, which facilitates the adoption of practices such as composting. However, this familiarity with biological processes does not automatically translate into the adoption of more elaborate techniques such as vermicomposting, which requires specific knowledge and regular technical monitoring. The use of raw waste as an amendment, particularly widespread in Kotédougou and Bama, testifies to this pragmatic appropriation of available organic resources, in a logic of spontaneous circular economy. Factor analysis reveals a social segmentation of preferences that transcends simple rural-urban opposition. The association between university level, single and preference for modern solutions echoes the work of (Zen *et al.,* 2014) in Malaysia, which identified educational capital as a major determinant of adoption of pro-environmental behaviours. However, this correlation should not be interpreted as an intrinsic superiority of sorting over composting because each modality responds to specific contexts and needs. The strong willingness to adopt composting and vermicomposting in Kotédougou coupled with a high demand for training, contrasts with the reluctance observed in Bobo-Dioulasso. This apparent paradox is explained by the direct economic value that these techniques represent for agricultural households. The work of (Marshall *et al.,* 2013) on the adoption of agricultural innovations has shown that the perception of a tangible and immediate benefit is a powerful driver of practice change, more effective than abstract environmental considerations. In Bobo-Dioulasso, the lack of direct agricultural use of composts limits their attractiveness, explaining the preference for delegated collection systems.

Adoption profiles and predictors of vermicomposting: The identification of the change in composting practice as the main predictor of the adoption of vermicomposting validates the hypothesis of gradual progression in agricultural innovations. According to the adoption scale model developed by (Pannell *et al.,* 2006), farmers tend to adopt innovations in successive stages, each step strengthening their ability to integrate more complex practices. Vermicomposting, which requires a finer management than traditional composting, is naturally part of this logic of gradual intensification of knowledge and know-how. Klöckner's work (2013) on environmental behaviour has shown that established habits facilitate or hinder the integration of new practices. Households that have already structured a sorting or composting system thus have a comparative advantage, not only in terms of technical skills, but also in terms of organizational capacity and intrinsic motivation. The central role of age and household size deserves a nuanced interpretation. In contrast to some studies that associate youth with greater openness to innovation (Prokopy *et al.,* 2008), the results suggest that maturity and experience can promote the adoption of demanding practices such as vermicomposting. This apparent contradiction can be explained by the specific nature of this innovation. Indeed, it requires residential stability, time investment capacity and a medium-term projection that younger and mobile households have less. As for the size of the household, its positive influence is probably explained by the availability of family labour for the regular monitoring of lumbricompostors, as well as by a greater production of organic waste. The significant contribution of the trainings received confirms the conclusions of (Lans *et al.,* 2016) on entrepreneurial learning of farmers. The acquisition of specialized technical skills is not limited to the transfer of information; it transforms the perception of possibilities and strengthens the sense of personal effectiveness, two crucial psychological factors in the decision to innovate. The gap between Kotédougou where the demand for training is at its peak, and Bobo-Dioulasso, where it remains moderate, suggests that capacity-building needs vary according to local contexts and existing management systems. The decision tree reveals the multiplicity of paths leading to the adoption of vermicomposting. The presence of multiple pathways leading to a high probability of adoption indicates that there is no single profile of potential adopter, but rather various combinations of favourable factors. This diversity calls for differentiated promotion strategies, adapted to the specificities of each segment of the population. The work of (Diederen *et al.,* 2003) on the uptake of agricultural innovations in the Netherlands had already stressed the importance of this heterogeneity and the need for targeted policies rather than uniform approaches. Finally, the concentration of maximum adoption probabilities in households combining advanced education, multiple training and structured waste management practices presents the typical portrait of an "early adopter" segment according to the typology of Rogers (2003). These households, representing a substantial proportion of the sample. They are priority targets for pilot projects whose success could then have a demonstration effect on less immediately receptive segments. The experience of spreading vermicomposting in India, documented by (Sinha *et al.,* 2008), has shown the effectiveness of this progressive approach.

CONCLUSION AND APPLICATION OF RESULTS

This research aimed to identify the socio-economic and behavioural determinants of the adoption of vermicomposting in three localities in the Guiriko region of Burkina Faso, mobilizing a predictive approach by Random Forest and decision tree. It also sought to explain the limited adoption of this promising technique, despite its demonstrated agronomic benefits, and to identify the household profiles most receptive to its uptake.

The results reveal four major findings. Vermicomposting is almost non-existent with 3.7% in Bobo, 2.2% in Bama and 0% in Kotédougou unlike sorting which reaches 25 to 38% depending on the locality. The willingness to adopt this technique varies significantly according to the urbanization gradient with p = 2.35e-30, Kotédougou showing the highest scores for composting at 2.9 and vermicomposting at 2.6, while Bobo favours sorting at 2.7. The desire for training follows the same trend with p = 6.1e-7 for vermicomposting, Kotédougou reaching 3.4 against 2.4 in Bobo. The Random Forest model with mtry = 7 achieves an accuracy of 77.45% and a kappa of 0.65, identifying the change in composting practice as the most determining variable with an importance of 18, followed by the current waste management at 13, the age and size of the household at 11. The decision tree distinguishes four adoption profiles with probabilities ranging from 0.04 to 0.29 for the very unlikely class comprising 3 to 9% of low-level agricultural households, up to 0.62 to 0.75 for the very likely class representing 35% of households with varying degrees of involvement in waste management. Decision-making coherence has a significant negative influence on the likelihood of adoption. These results provide three major contributions to the literature on the adoption of agricultural innovations in sub-Saharan Africa. The study documents for the first time the specific determinants of vermicomposting in Burkina Faso, filling an important empirical gap. Factor analysis reveals that vermicomposting has the most elitist adopting profile of the three practices studied, almost exclusively associated with academics and civil servants, which explains its low diffusion in a context where agricultural profiles with little education dominate. The findings further indicate that adoption is shaped not only by material and economic constraints, but also by cognitive and attitudinal factors. In particular, decision coherence emerges as a significant predictor, highlighting a psychosocial dimension that previous studies on waste management in West Africa have largely overlooked. The use of machine learning methods to model the adoption of environmental innovations is an innovative methodological approach in the Sahelian context, opening up prospects for targeted interventions based on predictive profiles rather than fixed socio-demographic categories.

CONFLICTS OF INTEREST: The authors declare that they have no conflicts of interest.

Ethics Statement: This study involved voluntary participation. Before completing the questionnaire, all participants were informed about the objectives of the research and provided their consent. Participation was anonymous, and all collected data were treated confidentially and used solely for scientific research purposes. Formal ethical approval was not required under the institutional and national regulations applicable to this study.

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