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Factors Influencing the Sustained Adoption of Innovative Techniques by Urban Farmers in Lubumbashi, Democratic Republic of Congo

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Abstract: A package of innovations was disseminated in urban agriculture and created real opportunities for employment, income, and the supply of vegetables of high nutritional quality. However, ten years later, farmers are working for a daily income of less than United State Dollars 1.25, and critical exceedances of heavy metal content standards in crops are recorded. Survey data collected from 202 farmers were used to identify, via the Logit model, the factors influencing the sustained adoption of the of two contrasting innovations of the package. The results of the exploratory survey of 537 farmers showed that 2.42% owned a motor pump, while the in-depth survey revealed that 25.2% of the 202 respondents were using motor pumps at the time of the survey. A total of 74.8% watered with buckets and watering cans. The high cost of the motor pump makes it inaccessible to farmers. Some tried to circumvent this constraint, which led to group purchases. Integrated soil fertility management was used by 58.4% of respondents. In total, 41.6% applied only chemical fertilizers. However, Integrated soil fertility management has been hampered by farmers' difficulties in accessing organic matter. The results of the Logit model revealed that no socio-demographic factors were significant for sustained adoption of the motor pump. They were relevant, rather, for integrated soil fertility management, where a single factor (mutual aid) appeared to play a role, albeit a moderate one. Economic factors such as land tenure status and diversification of income sources were significant for a sustained adoption of the motor pump. In contrast, no economic factors were significant for a sustained adoption of the integrated soil fertility management. Institutional factors such as access to credit and membership in an association were significant for sustained adoption of the two of innovations studied. A series of avenues to follow to improve the productivity of farms is proposed. We suggest an in-depth study of the mutual aid practiced by 86.1% of the farmers. The results of this study can be taken into account in research and policy aimed at improving adoption of innovative techniques that are beneficial to farmers in developing countries.

Keywords: urban agriculture; innovative techniques; sustained adoption; mutual aid; Lubumbashi; Democratic Republic of the Congo

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1. Introduction

According to the latest World Economic Forum report, about 70% of the African population depends on agriculture for their livelihood. This makes agriculture a critical sector on the African continent. Nevertheless, agricultural productivity is low and food insecurity remains a challenge [1]. Many development initiatives focus on improving the production and productivity of smallholders [2].

One of the factors explaining low agricultural productivity is the nonadoption by farmers of agricultural innovations developed by agronomic research [3]. The improvement of agricultural productivity has always been related to the state of technology and the

efficiency with which factors of production are used [4], hence the interest in analyzing the process of sustained adoption of agricultural innovations [3]. Moreover, several studies emphasize that the sustained adoption of an agricultural innovation depends mainly on socio-demographic [5], economic [6,7], and institutional characteristics of potential adopters [8,9]. In this paper, we propose to identify the factors that influence the sustained adoption of agricultural innovations by smallholder urban farmers in a developing country.

The widespread armed conflicts in the Democratic Republic of the Congo (DRC) and the development of mining activities have attracted many people to the copper-rich city of Lubumbashi in the hope of finding peace and work. Unfortunately, unemployment affects all social groups, regardless of their level of education [10]. In addition, the serious economic crisis observed since the 1990s and following the bankruptcy of the main mining company, Gécamines, coinciding with a period of spectacular demographic explosion [11], increase in urban poverty [12], and food dependency [13], prompted Lubumbashi's estimated six million inhabitants to engage in informal income-generating activities for survival [10,12]. These activities mainly concern urban agriculture, which mostly draw on the production and seasonal marketing of short-cycle vegetable crops. The vegetable farmers of Lubumbashi make use of the hydromorphic soils (considered rich) available in the lowlands of the valleys [14,15], stream water [14,16], borehole water, and climate [15].

In order to develop urban agriculture while offering real opportunities for employment, income, and daily supply of fresh products of high nutritional quality to city dwellers, the Urban and Periurban Horticulture (HUP) project (HUP-FAO: GCP/DRC/028/BEL), funded by the Kingdom of Belgium and executed by FAO through the National Service for Urban and Periurban Horticulture (SENAHUP), was implemented in the area from 2000 to 2010. This had five specific immediate objectives: securing access to resources (land, quality water); securing sustained and high-quality horticultural production; securing the institutional context and appropriation of the project by the actors in the sector; securing outlets, including the promotion of consumption, as well as securing dissemination and access to training.

Thanks to the project's activities, a package of innovations containing integrated production and protection techniques (IPP) was promoted to 7981 urban and periurban farmers, of whom women represented more than 69.2% [15,17]. This package essentially included: exotic crops (Chinese cabbage, cabbage, etc.); the use of motor pumps for irrigation; integrated soil fertility management (ISFM) based on the valorization of organic matter and the reasoned use of chemical fertilizers composting, ploughing in beds, crop association, and rotation; disease-resistant varieties, utilization of plant extracts with insecticidal effects; and the rational use of agrochemicals [17].

The project activities reports indicated that vegetable farmers of Lubumbashi are receptive to innovations and have adopted a series of good farming practices while reducing the use of chemical fertilizers and crop protection products [15,17]. While farming was formerly based on local crops such as *Brassica carinata* L., (locally called Kilanga) and *Amaranthus* spp., (Lenga-Lenga), the adoption of new crops by farmers in Lubumbashi has been spectacular. Moreover, 29% of the farmers supervised have bought motor pumps to irrigate their crops themselves [17]. The same report underlines that the IPP concept has been visibly and effectively implemented on ground. The HUP project has therefore notably contributed to supplying urban dwellers with vegetables of good nutritional quality and to reducing urban unemployment [15].

However, ten years later, studies report poor economic performance of farms in Lubumbashi [18], critical exceedance of heavy metal content standards in crops [14], and the worsening of poverty of farmers [12,19]. In addition, more than 60% of food products, including fruit and vegetables, consumed in Lubumbashi are imported [13]. Moreover, farmers are once again faced with the constraints of land insecurity [20], soil degradation, soil pollution by heavy metals [16], and attacks by pests such as *Agrotis ipsilon* L. larvae (cutworms locally called "Bilulu") [18,20]. Although the adoption of some of the innovations promoted by the HUP project, such as the culture of Chinese cabbage (*Brassica chinensis* L.),

improved seeds, and growing beds, are massive and long-lasting [17,21], the maintenance by farmers of certain other innovations in the same package seems to be more contrasted.

Given the above, the objective of this study was to use an econometric approach to identify the socio-demographic, economic, and institutional factors that influence the sustained adoption of innovations by small-scale vegetable farmers in Lubumbashi.

To this end, two innovations from the HUP project package were selected for this study: the use of a motor pump and the implementation of ISMF practices. These two innovations fall, respectively, into the categories of mechanization, and agricultural infrastructure and natural resource management [8]. The following criteria motivate the choice of these two contrasting innovations: (i) they have different implications because the motor pump requires a significant investment and ISFM requires changes in practices; (ii) compared to the other innovations in the package for which the adoption remains massive, and to the others that have not been adopted, the two innovations selected allow for a contrasting explanation of the factors of sustained adoption; and (iii) these two innovations have not been previously studied in urban agriculture in Lubumbashi.

Understanding the reasons for the contrasting adoption is important in the search for alternatives to improve the economics and sanitation of vegetable farms in Lubumbashi. Furthermore, the identification of the factors of contrasting adoption will orient policies in order to promote innovations in urban agriculture of developing countries.

Through the choice of these two types of contrasting innovations, it is reasonable to hypothesize that the factors that could motivate or hinder their sustained adoption will not be the same.

2. Materials and Methods

2.1. State of the Art on the Adoption of Agricultural Innovations

The adoption of an innovation refers to the decision of an adopter, the small-scale farmer in Lubumbashi, to make sustained use of the motor pump and ISFM promoted in the HUP project package (2000–2010) in Lubumbashi.

Adoption theory combines components of decision and diffusion theory to explain the decisions that motivate or hinder farmers to adopt an agricultural innovation. To achieve the objective of this study, we have identified three theoretical approaches to the adoption of an agricultural innovation in the literature, namely, the innovation–diffusion approach, the economic constraints approach, and the user context approach [8,22].

The innovation–diffusion approach assumes that information is an important parameter because it controls the spread of an innovation in the society. This approach focuses on the intrinsic characteristics of the innovation and their impact on its diffusion. It is based on the assumption that society is composed of a range of adopter categories, from early adopters to late adopters [23]. This assumption allowed us to place all the farmers selected by the study in the same context with regard to their level of knowledge relating to the innovations disseminated by the HUP project (2000–2010). Indeed, extension agents testified that they continued to disseminate HUP project innovations to new farmers after the project ended, which was also confirmed by the new farmers interviewed. It can thus be assumed that all selected farmers have confronted the information on the HUP package to such a sufficient extent that this parameter no longer needs to be of importance in explaining adoption.

The economic constraints approach focuses on the resources available to the farmer [24]. This approach suggests that economic characteristics, at the individual level, impact farmers' decision to adopt an agricultural innovation. Based on a literature review, this approach helped to identify the economic characteristics of farmers that may motivate and/or hinder decisions to adopt innovations in a sustained way [8,25].

The user context approach is based on the hypothesis that a farmer's decision to adopt an innovation is influenced by his socio-demographic profile and the institutional framework that characterizes his working environment [26,27]. This approach has allowed

us to identify the socio-demographic and institutional characteristics that may motivate and/or hinder farmers' decisions about the sustained adoption of innovations.

In line with several empirical studies that have developed econometric models while combining variables used by the different approaches to explain the decision of the sustained adoption of an innovation by a farmer, [8,9], the present study makes use of a combination of variables derived from the economic constraints approach and the user context approach to model the decision of sustained adoption by farmers in Lubumbashi.

The selected socio-demographic variables are gender, age, level of education, marital status, farmer experience, mutual aid, and perception of innovation. Those derived from economic characteristics include land tenure status, farm size, daily income, and income sources diversification, while those derived from institutional characteristics include farmer membership of an association, contact with the extension service, access to training, access to a subsidy, and access to credit.

As shown in Table 1, the selected variables were subsequently considered as research hypotheses. These hypotheses were expressed in expected signs of influence and were formulated based on the results of the meta-analysis conducted by [8] on 367 published regression models of the two types of innovations and also take into account the results of 13 similar studies in other contexts [28]. The literature highlights that gender and age of the farmer are likely to negatively influence the adoption of the motor pump. In contrast, farm size and subsidies are likely to negatively influence ISFM adoption. For both innovation categories, a positive sign is expected for all other predictors. The unreferenced predictors were not found in the dedicated literature that was consulted. The hypotheses for these unreferenced predictors were formulated based on the results of our exploratory survey in the same study area.

Table 1. Predictors used in binary logistic regression (Logit model).

Categories	Predictors	Description of the Explanatory of the Equation	Expected Signs			
			AMI (Motor Pump)	References	NRM (ISFM)	References
Socio-demographic predictors of sustained adoption.	Gender	1 = Female; 0 = Male	-	[29,30]	+	[31]
	Age	1 = older: >45 years; 0 = young: ≤45 years	-	[8,28]	+	[8]
	Study	1 = educated; 0 = not educated	+	[28,30]	+	[7,8]
	Marital status	1 = Married, 0 = Unmarried	+	-	+	[6]
	Experience	1 = Long ≥ 10 years; 0 = short < 10 years	+	[8,32]	+	[8]
	Mutual aid	1 = Yes; 0 = No	+	-	+	-
	Perception	1 = Good; 0 = Bad	+	[9]	+	[33,34]
Economic predictors of sustained adoption.	Land status	1 = Landowners; 0 = Tenant farmer	+	[28]	+	[8,31]
	Farm size	(1 = Large: > 4 acres; 0 = Small ≤ 4 Ares)	+	[8,28]	-	[8]
	Daily income	1 = High: ≥USD 1.25; 0 = Low: <USD 1.25	+	[28,30]	+	[6]
Institutional predictors of sustained adoption.	Diversification of income sources	1 = Yes; 0 = No	+	[8]	+	[33,35]
	Membership of an association	1 = Yes; 0 = No	+	[8,28]	+	[34]
	Contact with the extension service	1 = Yes; 0 = No	+	[9]	+	[8,34]

Table 1. *Cont.*

Categories	Predictors	Description of the Explanatory of the Equation	Expected Signs			
			AMI (Motor Pump)	References	NRM (ISFM)	References
	Have been trained in market gardening	1 = Yes; 0 = No	+	[9]	+	[36,37]
	Access to agricultural subsidy or donation	1 = Yes; 0 = No	+	[9]	-	[36,37]
	Access to credit	1 = Yes; 0 = No	+	[8]	+	[8,31]

Legend: categories of innovations that fall under agricultural mechanization and infrastructure (AMI), categories of innovations that fall under natural resource management (NRM), integrated soil fertility management (ISFM).

2.2. Presentation of the Study Area

Lubumbashi (11°27′47″ S and 27°19′−27°40′ E) is the capital city of the Haut-Katanga province and the second most-populated city of the DRC [38]. It is located less than 20 km away from the border with Zambia. This city has a CW climate type according to Köppen's classification. It is characterized by a rainy season (November to March), a dry season (May to September), and two transition months (April and October) [39]. With an average annual temperature of 20 °C (minimum of 8 °C and maximum of 32 °C), annual rainfall amounts to 1270 mm with extremes of 717 and 1770 mm [11].

The rainfall deficits observed since 1980 pose enormous difficulties in terms of water supply, especially in the dry season. These climate variations disrupt the agricultural calendar, and water is becoming a major handicap for urban vegetable farming, which is practiced out of necessity during the dry season [21]. Nevertheless, farmers take advantage of the physical potential (streams, shallows) of the area to water their crops [15]. Lubumbashi's soils are acidic and belong to the ferralsol group, which are deemed poor [40]. However, there are also hydromorphic soils in the valley bottoms [16]. These naturally rich soils, on which urban agriculture is mainly practiced, need to be drained in the rainy season and watered in the dry season. Due to the lack of means and appropriate drainage techniques, urban agriculture is hardly practiced in the rainy season.

Furthermore, although vegetable farming in Lubumbashi is practiced on hydromorphic soils, the cultivation of these soils leads to an accelerated reduction in their organic matter content and to the collapse of their chemical, biological, and physical fertility [40]. Due to their topographical position, these soils accumulate waste enriched with heavy metals from the mineral processing plants installed around and in the city of Lubumbashi [14,16].

Currently, urban agriculture in Lubumbashi is based on the production of Chinese cabbage under "monoculture" systems. Moreover, ten years after its promotion in the HUP project package, the adoption of Chinese cabbage by the farmers of Lubumbashi remains obvious. Chinese cabbage (*Brassica chinensis* L.) is a species of the Brassicaceae family cultivated for its leaves. It is the most widely consumed vegetable in Lubumbashi, especially during the dry season, and the Chihili variety is the most widely grown [41]. Despite the presence of the National Seed Service (SENASEM) in Lubumbashi, almost all the improved Chinese cabbage seeds used by farmers come from southern African countries.

Farmers justify the choice of Chinese cabbage for the following reasons: (i) its adaptation to the soil and weather conditions of Lubumbashi, (ii) its short production cycle (45 days on average), which allows the farmers to maximize income in terms of production frequency in the face of land constraints that characterize urban agriculture in Lubumbashi, whatever the production site, and (iii) its resistance to pest attacks. The main components of the technical itinerary for Chinese cabbage include nursery work, soil preparation based mainly on the establishment of beds, sowing/transplanting of seedlings, application of

phytosanitary products, application of fertilizers, and the sale of standing vegetables. Chinese cabbage is generally grown at a density of 20 cm × 20 cm [20]. For instance, Figure 1 shows Chinese cabbage plots in a vegetable farm of Lubumbashi.

Figure 1. Chinese cabbage plots in a vegetable farm of Lubumbashi.

2.3. Selection of Vegetable Farming Sites and Farmers

Using the archives of the provincial Ministry of Agriculture and Rural Development, National Service of Urban and Periurban Horticulture (SENAHUP), and the HUP project, scientific articles and field visits with the technical support of a partner NGO (namely the Diocesan Development Office and the Women's Development Network), it was possible to locate 25 vegetable production sites in the city of Lubumbashi (Figure 2). The following criteria were used to select the sites for the surveys. The sites had to: (i) be located in an urban area, i.e., within the boundaries of Lubumbashi; (ii) have been listed among vegetable production entities supported under the HUP project; (iii) be among the largest vegetable farming sites of Lubumbashi in terms of the intensity of farming activities; (iv) be accessible, and (v) be the subject of our exploratory survey in April and August 2019 that focused on urban and periurban sites. Facing a lack of statistical data on the research sites, this exploratory survey made it possible to contextualize the urban agriculture of Lubumbashi and to establish the economic performance of the farms. To participate in the in-depth survey, the farmer had to (i) be one of the farmers in the seven urban sites selected for the study, (ii) have Chinese cabbage as the main crop, (iii) voluntarily agree to participate in the survey, and (iv) be one of the 537 farmers surveyed during the exploratory survey in the urban and periurban sites. During the in-depth survey, it was found that some farmers previously surveyed could not be found in the sites. These farmers were replaced by other ones. The in-depth survey was based on a randomized design. Currently, it represents the largest survey of urban agriculture in Lubumbashi, and no other statistical sources exist. It can be assumed that the surveyed sample is well-representative of the whole urban-farmers population.

2.4. Data Collection

The methodology adopted for data collection was based on: (i) Information accessed through a review of HUP project reports and existing statistics. (ii) An exploratory survey of 537 farmers in the 13 sites selected among the 40 located in the urban (25 sites) and periurban (15 sites) areas of Lubumbashi. The exploratory survey covered the period from April to August 2019. This survey made it possible to identify the equipment and tools owned by the farmers and to establish the price of Chinese cabbage. (iii) An in-depth survey focused on the adoption of innovations, which consisted of the administration of

structured questionnaires to 202 farmers in the 7 sites (Table 2) selected from the 25 located in the urban areas of Lubumbashi (Figure 1). The in-depth survey covered the period from April to August 2020. This is the period during which vegetable farming activities are most intense in Lubumbashi. (iv) Finally, additional observations that were carried out in farms in order to cross-check the information provided by the respondents during the surveys with practices related to the use of the motor pump and ISFM.

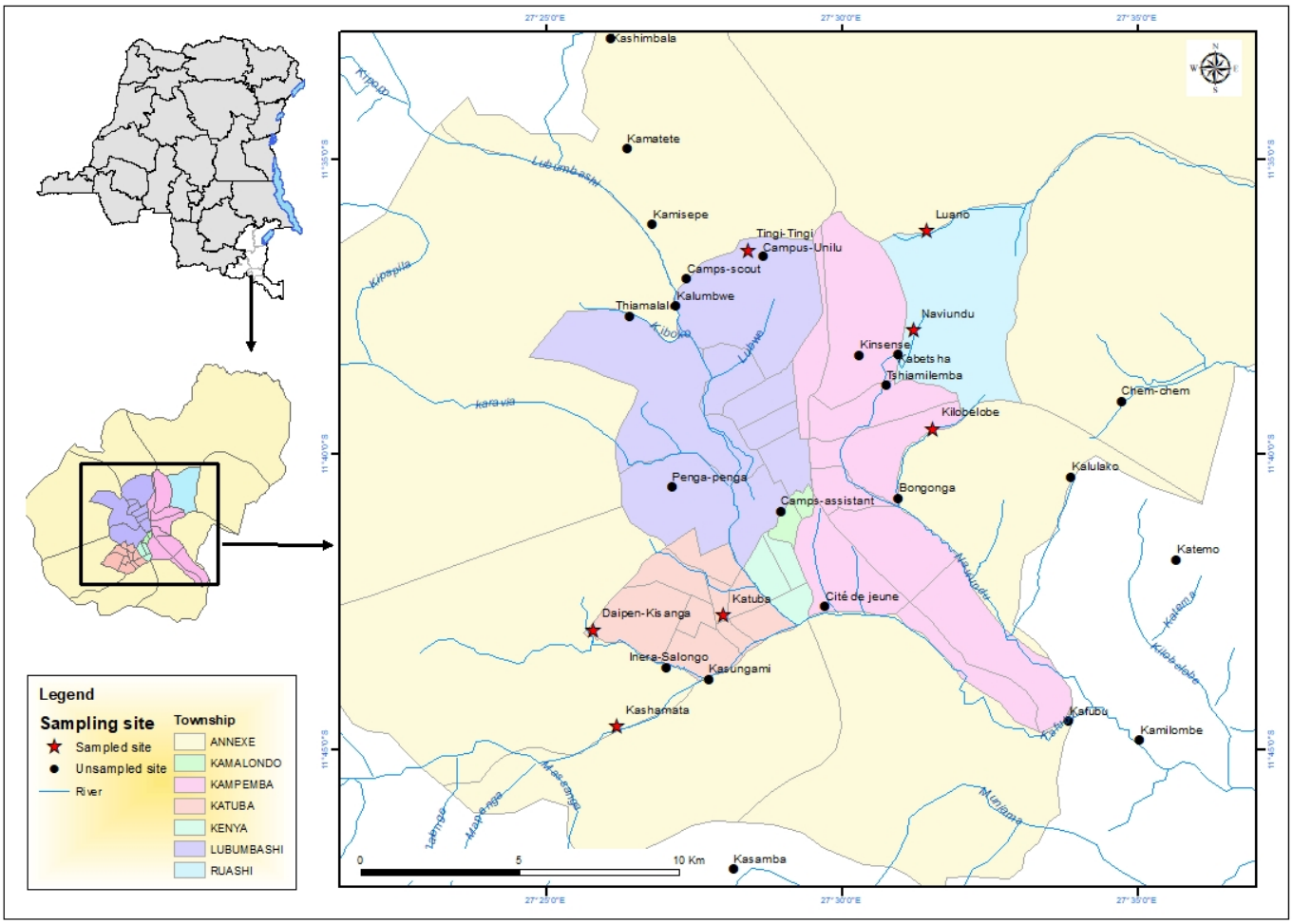

Figure 2. Location of urban agriculture sites in Lubumbashi.

Table 2. Distribution of producers according to the sites selected for the study.

Names of Selected Sites	Geographical Co-ordinates	Number of Respondents
Daipen	"11°42′978″ S"; "27°25′795″ E	28
Kashamata	"11°44′612″ S"; 27°26′188″ E	20
Katuba area	"11°42′729″ S"; 27°27′988″ E	42
Kilobelobe	"11°36′560″ S"; 27°28′422″ E	23
Luano	"11°36′222″ S"; 27°31′444″ E	27
Navuindu	"11°37′906″ S"; 27°31′208″ E	40
Tingi-Tingi	"11°36′560″ S"; 27°28′423″ E	22
Total		202

2.5. Data Processing and Analysis

The data collected were entered and recorded in an Excel file and analyzed using the IBM SPSS Statistics 21.0. Binary logistic regression (Logit model) was used to identify socio-demographic, economic, and institutional factors influencing the sustained adoption of the motor pump and ISFM by the respondents. The adoption of innovations was modeled as

the choice of a farmer between two alternatives: having adopted (1) or not having adopted (0). The model is presented as follows:

$$Y = f(x, e) \tag{1}$$

where Y is the dependent variable (having used the motor pump or the ISFM); x is the matrix of variables that can explain the variation in Y; and e is the logistic error of the distribution. The estimation of the Logit model is based on the maximum likelihood method. *Pi* is the probability associated with the survey unit.

$$Pi = f(Ii) = \frac{1}{1 + e^{-Ii}} \tag{2}$$

$$I = \beta 0 + \beta 1 Xi1 + \beta 2 Xi2 + \beta 3 Xi3 + \beta 4 Xi4 + \ldots + \beta nXin \tag{3}$$

Ii is a vector representing the characteristics of the survey unit and its choice decision; the βi represent the coefficients of the explanatory variables; and the Xin represent the explanatory variables [42]. The choice of the Logit model was motivated by the fact that it is a close approximation to the cumulative normal function on the one hand, and on the other hand, because it is mathematically simple and leads to a meaningful interpretation. This model has been used in several other studies that have identified factors influencing the adoption of innovative techniques by farmers in developsing countries [3,28]. This study considered $\alpha < 0.05$ as the threshold level of statistical significance.

3. Results

3.1. Characteristics of the Respondents and Their Farms

The results below provide an overview of our sample and thus of the current situation of urban agriculture in Lubumbashi. Given the survey design and random recruitment of respondents, it can be objectively assumed that the characteristics distribution among respondents is representative of the whole population.

The results in Table 3 indicate that there is a slight disparity in the distribution of respondents by gender. These results show that women (53.5%) were slightly more numerous than men (46.5%). Compared to the conclusion of the HUP project report ten years ago, which estimated the participation of women in market gardening in Lubumbashi at 69.2%, our results show that this participation of women has decreased [17]. The same observation was also made during a 2017 survey conducted in the same study area. The results of the latter highlighted the changing nature of urban agriculture actors in Lubumbashi and pointed out that men, once rare in vegetable production, are increasingly interested in the activity [20]. These same observations were confirmed by the results of our exploratory survey conducted between April and August 2019. Our discussions with farmers and our observations in the field have revealed that women, who used to be the vast majority in market garden production, are increasingly handing over the management of their farms to unemployed men, who are generally their husbands, while women are more concentrated in petty trading activities that bring additional income to the household.

Regarding the age of the farmers in the Table 4, the farmers surveyed were aged between 17 and 72 years, and the average age was 44.3 ± 13.1 years. The majority (56.4%) of the respondents were in the "45 years or less" age category. The results show that almost all of the farmers surveyed (95.5%) were educated, and the majority (75.2%) were married.

Almost all of the respondents (92.1%) had less than 10 years of experience in market gardening. This indicates that only a small proportion of farmers were able to benefit from the dissemination of innovations provided by the HUP project during project implementation. To ensure production, less-experienced farmers received information on HUP project innovations from extension services and from more-experienced farmers who had participated in project activities.

Table 3. Farmers' socio-demographic characteristics.

Variables	Modalities	Percentage (%)
Gender	Female	53.5
	Male	46.5
Age	Oldest: >45 years old	43.6
	Young: ≤45 years	56.4
Study	Educated	95.5
	Not educated	4.5
Marital status	Married	75.2
	Unmarried	24.8
Experience of the farmer	Long: >10 years	7.9
	Short: ≤10 years	92.1
Mutual aid	Yes	86.1
	No	13.9
Farmers' perception of innovation	Good	64.4
	Bad	35.6

Table 4. Farmers' economic characteristics.

Variables	Modalities	Percentage (%)
Land status	Landowners	44.8
	Tenant farmer	55.2
Size of the farm	Large: >4 acres	30.7
	Small: ≤4 acres	69.3
Daily income	High ≥ USD 1.25	34.7
	Low < USD 1.25	65.3
Diversification of income sources	Yes	8.9
	No	91.1

In agriculture, mutual aid is seen as a form of informal co-operation and mutual sharing of resources and know-how. Other benefits of mutual aid include access to a more experienced workforce, risk reduction, and the sharing of ideas among farmers [43]. Our results showed that 86.1% of farmers surveyed confirmed that they had practiced mutual aid. Finally, 64.4% of respondents said they had a good perception of innovations.

Land is a key factor in agricultural production, and the mode of access to it can influence the emergence of the activity and even agricultural practices in terms of farm sustainability [8]. In light of the above results, more than half, i.e., 55.2%, of the farmers surveyed stated that they rented their land through usufruct from communal, religious, and traditional authorities. The remaining farmers owned their land by inheritance or purchase. Despite the creation (as part of the HUP project) of a Municipal Consultation Committee on Land Matters, access to land for market gardening remains a challenge. Indeed, the majority (69.3%) of the farmers surveyed cultivate small areas of less than 0.04 ha. For an average production cycle of 45 days, 65.3% of the farmers obtain a daily income of less than USD 1.25. Finally, almost all of the farmers surveyed (91.1%) claimed they had no other source of income. This shows the role that urban agriculture plays in the survival of poor households in Lubumbashi.

A farmer's membership in an association provides information on the relationship he or she can develop with other farmers in his or her environment and facilitates the farmer's access to new agricultural technologies. It may have a role in explaining why an innovation is adopted or not. The above results in Table 5 show that the majority (65.4%) of the farmers surveyed are not members of any farmers association. In our discussions with the farmers we surveyed, some of them accused association leaders of being selfish, particularly with regard to the equitable sharing of donations obtained on behalf of the associations. This could lead to conflicts that resulted in the dysfunction or even the disappearance of the associations.

Table 5. Farmers' institutional characteristics.

Variables	Modalities	Percentage (%)
Membership of a market garden association	Yes	35.6
	No	65.4
Contact with the extension service	Yes	50.1
	No	49.9
Access to training	Yes	66.3
	No	33.7
Access to agricultural subsidies	Yes	50.1
	No	49.9
Access to agricultural credit	Yes	22.8
	No	77.2

Half of the farmers surveyed stated that they were in contact with the extension service. The extension service is a specialized service of the Ministry of Agriculture in the DRC in charge of co-ordinated extension and farmers' training activities throughout the country using harmonized extension approaches and/or languages and providing technical and material support for extension activities. Then, 66.3% said they have benefited from training on the practices promoted by the HUP project. Half of the farmers interviewed said they had received an agricultural subsidy. However, state subsidies are almost nonexistent in Lubumbashi. Therefore, subsidies must be understood as all forms of donations of inputs, tools, and training that farmers receive from international or local organizations through development projects, nongovernmental organizations, and any person of good will. Access to credit is often identified as a motivating factor for farmers to adopt innovations [8,31]. Only 22.8% of the respondents reported they have access to credit. The vast majority of farmers thus face funding challenges. The official banking systems do not grant loans to farmers.

These banking systems describe vegetable farming as an informal activity with low repayment capacity. Farmers in Lubumbashi perceive credit as any form of unofficial loan that can be used to fund vegetable growing activities. These loans include, among others, the tontine (locally called Kinkurimba) and loans from informal moneylenders with prohibitive interest rates.

The results in Table 6 show that the average size of a vegetable farm in Lubumbashi was 0.0464 ± 0.0256 ha and the Tukey test shows no significant difference between farms in the selected sites. Vegetable farming is carried out by family labor. On average, 2.27 ± 0.89 members of a household work permanently on a farm. Tukey's test shows a significant difference between the sites in terms of family workforce (p value = 0.000). Farms in sites such as Katuba, Luano, and Naviundu have used more labor than those in other sites.

Table 6. Farm size and permanent workforce.

Selected Sites	Number	Size of Farms in Are	Family Workforce	Working Time per Day (Hours)	Total Working Time (Hours) Per Production Cycle
Daipen	28	5.19 (2.45)	2.11 (0.92) (ab)	5.5 (0.6)	247.5 (29.8)
Kashamata	20	5.59 (2.41)	2.25 (1.02) (ab)	5.7 (0.6)	257.6 (27.7)
Katuba area	42	5.07 (2.64)	2.55 (1.04) (a)	5.6 (0.5)	251.5 (24.1)
Kilobelobe	23	4.89 (2.29)	2.17 (0.78) (ab)	5.3 (0.9)	242.5 (41.2)
Luano	27	3.78 (2.32)	2.52 (0.84) (a)	5.8 (0.6)	259.1 (25.2)
Naviundu	40	4.36 (2.81)	2.38 (0.74) (a)	5.5 (0.5)	248.7 (27.2)
Tingi-Tingi	22	3.57 (2.29)	1.59 (0.50) (b)	5.6 (0.6)	251.3 (24.6)
	Average	4.64 (2.56)	2.27 (0.89) ***	5.6 (0)	251.8 (27.7)

Standard deviation in bracket. *** = Indicates a very highly significant test at 5%, Means with letters are not significant and means with different letters are significant.

The low level of family workforce recorded in the Tingi-Tingi farms is due to the fact that this site was more dominated by student farmers (due to the proximity of the University of Lubumbashi campus). These students were generally single and worked individually. However, the sites of Katuba, Luano, and Naviundu are the largest production areas of Chinese cabbage in Lubumbashi. In these sites, household members were more motivated to support the success of the farms to survive. This justifies the presence of a large family workforce on the farms in these sites. The results (Table 6) of the exploratory survey at the sites involved in this study showed that farmers in Lubumbashi spend an average of 5.6 ± 0 h per day on their farms. For a Chinese cabbage production cycle of about 45 days, they work 251.8 ± 27.7 h, or 1259 h, for about five production cycles per year.

3.2. Factors Explaining the Sustained Adoption of the Innovations Studied

3.2.1. Rate of Adoption of the Motor Pump and the ISFM

The results of the in-depth survey showed that 25.2% of the surveyed farmers reported using a motor pump during the outstanding production cycle. This adoption rate appears to be down from that recorded by the HUP project at the time of the motor pump's dissemination. In our discussions with farmers, most of them said that they needed motor pumps to reduce the drudgery of manual watering. However, the cost of purchasing a motor pump (USD 145.66 or EUR 119.62) constrains farmers' access to it, so they resort to manual watering with watering cans and buckets. The results of the exploratory survey indicate that very few farmers, 13 out of a total of 537, owned the motor pumps. There are some sharing mechanisms that allow farmers to access the motor pump without owning it. In contrast, more than half (58.4%) of the farmers surveyed have used the ISFM. This adoption rate appears to remain high as it was at the time of its dissemination by the HUP project. The remaining 41.6% used only chemical fertilizers. In our discussions with farmers, some cited difficulties in accessing organic matter as the main constraint to implementing the ISFM but many of them are finding solutions to access organic matter that will be highlighted below.

3.2.2. Modeling Predictors of Sustained Adoption of Innovation

The sign of the coefficients as well as the odds ratios labeled by Exp(B) indicate the direction of the relationship between variables in the equation. The Wald statistic plays the same role as the *t*-test and shows the contribution of each predictor to the improvement of the model.

The results (Table 7) highlight the positive influence of five of the seven socio-demographic factors in the equation in the sustained adoption of motor pumps. These factors are education, marital status, experience, mutual aid, and perception of innovation, while gender (female) and age have a negative influence on the sustained adoption of a motor pump. However, the results also show that none of the socio-demographic factors are significant in the sustained adoption of the motor pump. Economic factors, land tenure status, daily income, and diversification of income sources are positively correlated with motor pump sustained adoption. On the other hand, only the size of the farm negatively influences the sustained adoption of the motor pump. Land tenure and income diversification were statically significant in the sustained adoption of the motor pump. Finally, four institutional factors are positively correlated with motor pump adoption. These factors include the farmer's membership to a growers association, contact with the agricultural extension service, access to training, and access to credit. Only access to subsidy negatively influences the adoption of the motor pump. Membership of a farmers association and access to credit were statistically significant for the sustained adoption of motor pumps.

Table 7. Logit model estimation in motor pump use.

Categories of Sociodemographic, Economic, and Institutional Factors	Coe A	Error St	Wald	Sig.	Exp (B)	CI for Exp (B) 95%	
						Inferior	Superior
Gender	−657	0.563	1.363	0.243	1.930	0.640	5.816
Age	−0.160	0.557	0.083	0.774	0.852	0.286	2.537
Study	1.144	1.192	0.921	0.337	3.139	0.304	32.454
Marital status	0.243	0.636	0.146	0.703	1.275	0.366	4.436
Experience of the farmer	0.977	0.641	2.324	0.127	2.658	0.756	9.336
Mutual aid	0.320	0.936	0.117	0.733	1.377	0.220	8.613
Perception of innovation	0.582	0.719	0.656	0.418	1.790	0.437	7.326
Land tenure status	1.040	0.523	3.945	0.047 *	2.828	1.014	7.887
Size of the farm	−0.172	0.642	0.072	0.788	0.842	0.239	2.963
Daily income	0.838	0.648	1.674	0.196	2.311	0.650	8.223
Income diversification	4.190	0.710	34.860	0.000 ***	66.027	16.430	265.334
Membership of an association	1.019	0.513	3.947	0.047 *	2.769	1.014	7.564
Contact with extension services	0.618	0.774	0.637	0.425	1.855	0.407	8.464
Access to training	0.340	0.946	0.129	0.719	1.405	0.220	8.967
Access to subsidies	−0.019	0.564	0.001	0.973	0.981	0.325	2.966
Access to credit	1.949	0.650	8.995	0.003 **	7.019	1.964	25.079
Constant	−7.243	2.078	12.148	0.000	0.001		

Number of observations = 202; −2 log likelihood = 124.119 a; R2 (Nagelkerke) = 0.613; *p*-value = 0.000 * = Indicates the significant test at 5%, ** = Indicates highly significant test at 5%, *** = Indicates a very highly significant test at 5%. CI = confidence interval.

The results also indicate that, compared to the hypotheses, most of the predictors of the motor pump's sustained adoption equation present the same expected signs of influence (Table 1). The exceptions are the size of the holding and access to subsidies, which are negatively correlated, while positive correlations were expected.

The results (Table 8) highlight the positive influence of socio-demographic factors in the sustained adoption of ISFM. These factors include gender, marital status, experience, mutual aid, and perception of innovation. In contrast, age and education are negatively correlated. Only mutual aid is statistically significant for the sustained adoption of the ISFM. As for economic factors, land tenure status and daily income are positively correlated, while farm size and diversification of income sources are negatively correlated. No economic factors are statistically significant for the sustained adoption of the ISFM. Finally, all institutional factors are positively correlated with the sustained adoption of ISFM. Association membership and access to credit are statically significant for the sustained adoption of ISFM. It is worth noting that these same two factors are also the only ones that are significant for both types of innovations. The results also showed that, relative to the hypotheses, most of the predictors in the ISFM's sustained adoption equation showed the expected signs of influence (Table 1). The exceptions were: age, education, and diversification of income sources, which were negatively correlated when positive correlations were expected. Second, access to grants was positively correlated when a negative correlation was expected.

Table 8. Logit model estimation of ISFM adoption.

Categories of Sociodemographic, Economic, and Institutional Factors	Coe A	Error St	Wald	Sig.	Exp(B)	CI for Exp(B) 95%	
						Inferior	Superior
Gender	0.523	0.421	1.547	0.214	1.688	0.740	3.849
Age	−0.001	0.464	0.000	0.998	1.001	0.403	2.484
Study	−0.724	1.041	0.484	0.487	0.485	0.063	3.730
Marital status	0.031	0.479	0.004	0.949	1.031	0.404	2.634
Experience of the farmer	0.011	0.489	0.001	0.981	0.989	0.379	2.580
Mutual aid	1.406	0.618	5.183	0.023 *	4.080	1.216	13.691

Table 8. *Cont.*

Categories of Sociodemographic, Economic, and Institutional Factors	Coe A	Error St	Wald	Sig.	Exp(B)	CI for Exp(B) 95%	
						Inferior	Superior
Perception of innovation	0.942	0.549	2.938	0.087	0.390	0.133	1.145
Land tenure status	0.203	0.435	0.217	0.641	1.225	0.522	2.873
Size of the farm	−0.625	0.638	0.960	0.327	0.535	00.153	1.868
Daily income	0.545	0.505	1.164	0.281	1.725	0.641	4.642
Income diversification	−0.701	0.544	1.664	0.197	0.496	00.171	1.440
Membership of an association	3.861	0.700	30.435	0.000 ***	47.508	12.052	187.273
Contact with extension services	0.047	0.553	0.007	0.932	0.954	0.322	2.820
Access to training	0.626	0.657	0.907	0.341	1.870	0.516	6.776
Access to subsidies	0.013	0.445	0.001	0.976	1.013	0.423	2.426
Access to credit	1.365	0.671	4.140	0.042 *	3.914	1.051	14.571
Constant	−1.260	1.300	0.940	0.332	0.284		

Number of observations = 202; −2 log likelihood = 174,475 a; R2 (Nagelkerke) = 0.506; *p*-value = 0.000, * Indicates the significant test at 5%, *** = Indicates a very highly significant test at 5%. CI = confidence interval.

4. Discussion

4.1. Factors in Farmers' Decision to Adopt a Motor Pump

The motor pump was promoted under the HUP project to alleviate the drudgery of manual watering. After its dissemination, the HUP project's activity report (2000–2010) indicated that 29% of the farmers in the 7981 supported farms bought motor pumps themselves with the credits offered by the project [17].

On the other hand, the results of our exploratory survey indicated that only 13 farmers out of a total of 537 surveyed owned motor pumps at the time of the survey. The results of the in-depth survey revealed that 25.2% of the farmers interviewed had watered their crops at least once with motor pumps. In our discussions, some farmers interviewed said that the high cost of purchasing a motor pump limits its access. In order to be able to use the pump, most of the users interviewed said that they had circumvented this constraint by making group purchases. The authors of [44] suggest that farmers look for new ways to achieve sustainability. One of such ways is participation in local food supply systems. This often requires new forms of co-operation between farmers [45]. Our results thus confirm the hypothesis of the economic constraints approach, which focuses on the resources available to the farmer [24].

The results of the binary Logit model highlight the influence of socio-demographic, economic, and institutional factors in the adoption of motor pumps (Table 7). In respect to the hypotheses translated into expected signs of influence, the results of the regression suggest that farm size and access to subsidies show contrasting signs compared to the literature consulted. The negative sign between motor pump adoption and farm size may indeed appear quite puzzling as it implies that vegetable farmers with large areas are less likely to adopt motor pumps than farmers with small areas. However, given that the whole sample is composed of relatively small-scale farmers, the result may indicate that having a larger area to manage is merely associated with additional costs of access to land, inputs, and labor without putting the farmer in a better position with regard to his or her global investment capacities.

Indeed, when a small-scale farmer in Lubumbashi expands his or her land and faces budget constraints, he or she is more likely to prioritize meeting the needs for access to land, inputs, and labor over the more expensive motor pump. Second, as a farmer becomes accustomed to donations, he or she is more likely to increase his or her dependence on them at the expense of efforts to be autonomous. These results are consistent with those found in Ethiopia, which showed that the low adoption rate of the motor pump by resource-poor farmers was justified by its high price relative to farmers' income [30,46]. The same results were found in Algeria in a study on factors influencing the adoption of innovation in agriculture [47].

4.2. Factors of Farmers' Decision to Adopt ISFM

For a very long time, urban agriculture in Lubumbashi was associated with certain unsustainable practices such as slash-and-burn agriculture, used by many farmers as a quick way to clear the land, and the abusive use of chemical fertilizers. These practices have only served to deplete the soil of organic matter and acidify the soil [42]. After the dissemination of the ISFM by the HUP project, the project evaluation report notes that farmers in Lubumbashi are receptive to integrated production and protection techniques, and have adopted a series of good agricultural practices promoted by the HUP project, while using less chemical fertilizer [17]. The results of our study showed that 58.4% of surveyed farmers were implementing ISFM during the outstanding production cycle. Although the project report does not mention the exact rate of adoption of the ISFM, it is important to mention that the rate of 58.4% seems to remain high as it was at the time of dissemination. The report indicates that prior to HUP's intervention, the combined use of chemical fertilizers and organic matter was not well-known among urban farmers. They used mainly chemical fertilizers and they used them excessively. After the project intervention, the use of natural fertilizers (chicken droppings and compost) increased dramatically, and farmers used chemical fertilizers rationally [15]. Our results showed that difficulties in accessing organic matter, accentuated by psychosociological factors, hindered the effective implementation of ISFM and forced some farmers to use much more chemical fertilizer than organic matter.

The results of the binary logistic regression show the influence of socio-demographic, economic, and institutional factors in the adoption of ISFM (Table 8). With regard to the hypotheses translated into expected signs of influence, the results on the ISFM regression suggested that age, education, diversification of income sources, and access to subsidies presented opposite signs compared to the literature consulted. The negative sign between ISFM adoption and age implies that older farmers are less likely to adopt ISFM than younger farmers. From our knowledge of the field, this could be explained by the difficulty for an older farmer to travel long distances in search of organic material from the broiler farmers scattered around Lubumbashi. The negative sign between ISFM adoption and level of education implies that more-educated farmers are less likely to adopt ISFM than less-educated farmers. This is because urban dwellers and even some urban authorities attach little importance to urban agriculture. One study shows that urban agriculture in Lubumbashi is perceived by some authorities and city dwellers as an informal activity and a sign of rurality that has no place in the city [48]. These views discourage educated farmers, who seek keeping their self-esteem and even their dignity. Therefore, the most-educated farmers are not prepared to walk through the city with or in search of organic matter; rather, they merely use chemical fertilizers. The negative sign between ISFM adoption and diversification of income sources implies that producers with additional off-farm income are less likely to adopt ISFM than those who rely solely on income from vegetables farming. During our in-depth discussions, some respondents stated that when a farmer finds additional income beyond that from vegetable farming, he/she will tend to focus more on the off-farm activity, or even be willing to abandon vegetable farming. These testimonies indicate that urban vegetable gardening in Lubumbashi is an emergency activity for households that face unemployment. For some farmers, additional off-farm income would mean the elimination of some of the difficulties associated with vegetable farming, which is seen as tough and less respectful. On the other hand, the positive sign between ISFM and subsidies implies that farmers who benefit from subsidies, which in this study are classified as input and tool donations, are more likely to adopt ISFM.

Indeed, farmers in Lubumbashi are more motivated to seek out organic matter when they have the financial means to purchase chemical fertilizers and to organize transport for the supply of organic matter. Organizing the transport of organic matter is an important way for farmers to circumvent psychosocial barriers that are amplified by the low regard for urban agriculture among the people of Lubumbashi. This is due to the fear of walking around the city with a bag of organic material on one's head.

4.3. Contrast between the Two Innovations Studied

This study focused on two categories of innovations promoted by the HUP project. These innovations are related to two distinct categories, i.e., mechanization and agricultural infrastructure (motor pumps) and natural resource management (ISFM). The results suggest that no socio-demographic factors are significant for sustained adoption of the motor pump, while they are slightly more of an importance for ISFM, for which one socio-demographic factor (i.e., mutual aid) seems to play a role (albeit a moderate one). It is worth recalling that mutual aid stands as the sole unreferenced factor in the literature on the adoption of both ISFM and a motor pump (see Table 1).

In addition, the same results showed that economic factors such as land tenure status and diversification of income sources were significant for the sustained adoption of the motor pump while none were significant for sustained adoption of ISFM. This is because the motor pump requires a considerable investment (economic capital), whereas ISFM is linked to changes in practices. When farmers have land security and diversified incomes, they tend to professionalize market gardening in order to change the image of urban agriculture, which has been tarnished by Lubumbashi's urbanites. To do this, farmers are willing to adopt more expensive innovations (motor pump) to reduce the drudgery of work and improve crop yields. One study points out that land pressure in urban agriculture leads many farmers to use cultivation practices that do not guarantee the sanitary quality of harvested products or crop yields, and [8,49] emphasize that land tenure is important for the adoption of agricultural technologies. This is because it can broaden farmers' planning horizons, and the lack of land security can make agricultural investment too risky. In addition, another study points out that off-farm income contributes significantly to financing agricultural activities and helps farmers meet basic needs [50]. In order to practice ISFM, farmers in Lubumbashi are forced to overcome psychosocial barriers to accessing organic matter. To do so, they resort to mutual aid. Currently, mutual aid has become an important social capital that is defined by the ability of producers to develop social cohesion in order to increase agricultural productivity and reduce poverty. The findings of [43] mentioned that the level of co-operation instituted in developing countries remains low due to the lack of trust in co-operative institutions. In the face of this, mutual aid systems that link smallholders together play a fundamental role in ensuring farm sustainability [51]. In Lubumbashi, for example, older farmers are willing to share their experiences with younger farmers. In return, younger farmers help older farmers with heavy tasks.

Our results also show that only institutional factors such as access to credit and association membership were significant for both types of innovations studied. The results of other studies affirm that, for a very long time, these two institutional factors have always been the focus of attention in studies on the adoption of agricultural innovations and have, for the most part, been significant for the adoption of the two innovations studied [8,34]. While the literature uses a dummy variable that takes a value of 1 if a farmer has access to credit [8], one study points out that this will only affect adoption if the farmer is credit-constrained [52]. Indeed, farmers' difficulties in accessing credit have always been cited as an important element of resistance to innovation adoption [53]. While there is growing evidence that access to finance by smallholders can lead to investments in improved adoption of technologies needed to increase agricultural productivity, the challenges associated with obtaining agricultural loans and credit should be minimized to make agricultural loans and credit financing more accessible to smallholder farmers [54]. Furthermore, membership of farmers organizations is often considered a form of social capital, but these organizations are also often used to disseminate information about new technologies, so this variable may in some cases be an indicator of awareness of an innovation [8].

5. Conclusions

The issue of promoting agricultural innovations is a major challenge for agricultural decision makers, particularly in developing countries. A development project promoting a package of innovations was implemented in the urban agriculture of Lubumbashi, which is characterized by poor economic and health performance. However, the majority of farmers stopped using the innovations in the package once the project ended. This paper identified the factors influencing the sustained adoption of two contrasting innovations from the promoted package. The results showed the importance of farmers' socio-demographic, economic, and institutional characteristics in the sustained adoption of the motor pump and ISFM.

The results of the exploratory survey of 537 farmers showed that only 2.42% of the respondents owned motor pumps, while the in-depth survey revealed that 25.2% of the 202 respondents used them. The remaining farmers watered with buckets and watering cans. The high cost of the motor pump makes it inaccessible to farmers. Some farmers tried to circumvent this constraint, which led to group purchases. In contrast, the ISFM was used by more than half of the respondents (58.4%). The others (41.6%) applied only chemical fertilizers. Difficulties in accessing organic matter limited the sustained adoption of ISFM. In order to practice ISFM, farmers would have to overcome psychosocial barriers that are amplified by the low regard for urban agriculture among the people of Lubumbashi.

The results showed that 65.3% of farmers work for a daily income of less than USD 1.25. In light of the results of this study, the lack of efficiency shown by urban agriculture in Lubumbashi would be justified by the farmers' use of ancestral practices that are not very productive. Instead, our results encourage farmers to use the innovations in the package promoted by the HUP project, notably, the motor pump and the ISFM, to improve the productivity and sanitary quality of the farms.

The results of the Logit model revealed that no socio-demographic factors were significant for sustained adoption of the motor pump. In contrast, they were significant for ISFM, where only one factor (mutual aid) appeared to play a role, albeit a moderate one. Mutual aid practiced by 86.1% of farmers helped farmers overcome some of the challenges related to the use of organic matter, heavy physical labor for older farmers, and psychosocial barriers for younger farmers. Extension services and development projects to promote agricultural innovations should consider the mutual aid network to facilitate the adoption of innovations by small-scale farmers. Economic factors such as land tenure status and diversification of income sources were significant for the sustained adoption of the motor pump. In contrast, no factors were significant for the sustained adoption of ISFM. This is because the motor pump requires a considerable investment, whereas ISFM is linked to changes in practices. Agricultural decision makers should revitalize the Municipal Concertation Committee (CMC) that was created to facilitate urban farmers' access to land.

The results showed that only institutional factors such as access to credit and association membership were significant for the two types of innovations studied. These results prompted agricultural decision makers to pay more attention to the institutional framework of agriculture, which has a significant impact on the sustained adoption of innovative techniques. Agricultural decision makers should facilitate access to credit, change the status of associations to make them more flexible, and increase incentives for farmers to join associations.

Finally, our results revealed that the factors and barriers to adoption identified for the two categories of innovations studied are contrasting, but that mutual aid has multiple virtues that can circumvent these barriers.

These results can help extension services that aim to build models for the dissemination of innovative techniques in the context of urban agriculture in developing countries. Our analysis suggests that the mutual aid practiced by most farmers should be further explored. It seems to play an indispensable role in small urban farms' viability.

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