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Factors Influencing the Choice of Storage Technologies by Smallholder Potato Farmers in Eastern and Southwestern Uganda

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Abstract: Potato is a key food and cash crop in Uganda, mainly produced by smallholder farmers in the eastern and southwestern highlands of the country. This study assessed different factors influencing the choice of storage technologies by Ugandan potato farmers. Data were collected from 240 potato farmers using structured questionnaires in key potato producing districts in eastern and southwestern Uganda. Data were analysed using descriptive statistics and the multinomial probit regression model. Results indicate that potato farmers have limited access to credit and adequate extension services. Furthermore, most of the potato production is sold immediately after harvest. Although significant quantities of potato are stored as food for the household and seed for the next season, very few farmers store ware potato for later sale at a higher price. The farmer households generally use light storage technologies designed for seed storage, while dark stores required for proper ware potato storage are rarely used. Results for factors influencing the choice of storage technologies were mixed, and the extent and direction of influence varied with technology. The predominant factors that positively influenced the choice of dark storage technologies or a combination of different storage technologies included monthly income from sources other than potato sales, access to storage management advice and access to credit. This study recommends enhancing farmers' access to adequate extension services and credit to promote good ware potato storage conditions.

Keywords: potato; storage; dark; light; extension services; credit; multinomial probit model; Uganda

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1. Introduction

Potato (*Solanum tuberosum L.*) is the world's number one nongrain food commodity and the fourth most important food crop after rice, wheat, and maize [1]. In 2019, the crop was cultivated worldwide on almost 17 million hectares (ha) with a total production of 370 million tonnes (t). China was the biggest potato producer (25% of the world's production), followed by India (14%), the Russian Federation (6%), Ukraine (5%), and the USA (5%) [2]. Over the years, the relative importance of potato has slowly shifted from developed to developing countries where potato is an important food and cash crop for smallholder farmers [3,4]. The crop has a short growing season, it stands out for its water use efficiency and productivity in terms of energy produced per unit area and time, and it is an inexpensive source of important micro-nutrients [5,6].

Potato is among the fastest expanding crops in Uganda, mainly driven by increasing demand from urban centres and changes in lifestyle by a fast-growing population. Traditionally cultivated in the western, southwestern, and eastern highlands of the country,

the potato has recently expanded to low- and midland areas in central and northwestern Uganda [7]. The smallholder production systems dominating national potato production, however, are characterised by small land parcels allocated to the crop and low yields ranging from 3 to 8 t/ha [8–10]. Despite the increasing production trends, Uganda faces several challenges along the potato value chain. First, low seed potato quality is considered one of the major factors leading to low yields. Potato farmers generally recycle their own seed from previous harvests or obtain their planting material informally from other farmers or in the open market. This seed is often infected with seed-borne pathogens [8]. Also, premature harvesting and poor harvesting techniques are major concerns negatively affecting tuber quality and leading to high yield losses [11]. Finally, inadequate postharvest handling and limited adoption of appropriate storage practices are major contributors to high postharvest losses estimated at 10–28% [3]. Especially diseases, rotting, and theft are considered by potato farmers as the leading causes of postharvest losses [12].

Due to its semi-perishable properties, appropriate and efficient postharvest technologies and marketing are critical to the entire potato production–consumption system. Potato can be stored to provide a uniform market supply throughout the year while maintaining the tubers in their most edible and marketable condition. However, processes like respiration, sprouting, changes in the chemical composition of the tuber, spread of diseases, damage by extreme temperatures, and evaporation of water from the tubers cause storage losses. Although storage losses cannot be avoided, they can be limited by choosing the suitable variety, optimal pre-storage and storage conditions, as well as adequate storage duration [13]. Good ware potato storage conditions include low temperatures and a dark, well-ventilated environment with high relative humidity [14]. The stored ware potato should also be treated with sprout inhibitors like radioactive irradiation. Irradiated potatoes are assumed not to constitute a health hazard. Irradiation of food products, however, is costly, and its acceptability is affected by the consumers' perceived risk to health consequent to their consumption [15,16].

Various advanced potato storage systems exist, including evaporatively cooled storage, cold storage, and CO_2 control system [13]. However, literature has shown that farmers and other value chain actors in eastern Uganda stored ware potato mainly using rudimentary storage methods [17]. These included the floor of houses mainly made of mud, cribs made from local materials, wooden purlins deep in the soil, sacks covered with tarpaulins and under the shades of trees. Besides, farmers in southwestern Uganda mainly stored their potatoes in the family house other than in recommended separate storage areas, collection centres and granaries [12]. The study further noted that potato was stored primarily on the floor, and only 4% of the farmers used recommended storage practices such as the use of raised wooden trays. Most frequently used traditional storage technologies are not effective, and they can keep potato tubers in good quality for a short period of only 2–5 weeks, depending on the potato variety. To promote good ware potato storage practices by farmers and traders in Uganda, however, improved individual and collective ambient stores have recently been introduced in the country's highlands. Both technologies are affordable, practical, and allow the stored potato to maintain its quality and consumer acceptability for at least nine weeks [18].

Despite the potential benefits, few Ugandan farmers and other value chain actors are engaged in storing ware potato for later sale. Potato farmers in eastern Uganda sell most of their production (78%) immediately after harvest, whereas 7% and 15% is consumed at home as ware potato and used as seed, respectively. This lack of ware potato storage for later sale leads to high seasonal price volatility that negatively affects most actors along the potato value chain, particularly when the supply exceeds demand [14]. Ideally, more farmers and traders should be storing long term for better prices and distribution of potato supply through periods of scarcity.

Social demographic and institutional factors influence farmers' adoption of different storage technologies. Factors such as family size, distance to the market, age, education, and membership of the household head in a farmer group or association positively affect

the use of improved storage technologies by grain farmers in Uganda [19]. The authors noted that other factors like access to credit and extension service delivery did not affect it. However, more research has confirmed that agricultural extension services through video messages significantly increased knowledge on potato storage and handling among potato farmers in southwestern Uganda [20]. The study did not look at the factors influencing farmers' choice and use of potato storage technologies. This knowledge is missing, despite being essential for scaling up and promoting the adoption of appropriate and feasible ware potato storage technologies by smallholder farmers, and was, therefore, the focus of this study.

2. Materials and Methods

This study was carried out in eastern and southwestern Uganda, the major potato producing areas of the country. Both regions have highland areas of 1500–3000 m above sea level characterised by deep volcanic soils, mild temperatures, and abundant rainfall. March–July (season A) and September–January (season B) are the two major potato growing seasons; however, some limited off-season production also occurs in swamps, valley bottoms, and irrigated areas.

A purposive sampling method was employed to select districts, subcounties, and parishes within the study area. The basis for selection was levels of potato production and potato marketing activities taking place. The districts of focus in this study were Kween, Kapchorwa, and Mbale in eastern Uganda and Kisoro, Rubanda, and Kanungu in southwestern Uganda. Further information on major potato producing subcounties and parishes was obtained from district-level government extension workers. Within each selected parish, villages were selected randomly. Within each selected village, the individual farmers interviewed were randomly selected from pre-established lists of male-headed and female-headed households living in that village. The total sample size was 240 farmers, of which 154 were male and 86 female household heads. This study was part of a broader survey assessing the current potato storage and marketing practices of farmers and traders in Uganda and the economic feasibility of long term ware potato storage with the objective to give strategic orientation to the development partners currently supporting the potato value chain promotion in Uganda. The survey was conducted in February–April 2019, and data on seasons 2017 B, 2018 A, and the off-season between the two main seasons were collected. Using pretested structured questionnaires, information was collected on the sociodemographic characteristics of farmers and traders as well as their households, their livestock and assets owned, their access to potato management advice, their group membership, their land ownership and use, their potato production, use and trade, their harvest and postharvest handling activities and related costs, their potato storage practices and related costs, their potato marketing activities and related costs, as well as other sources of income. The sources used to compose these questionnaires were the at that time publicly available literature on the Ugandan potato value chain.

Potato farmers' socioeconomic characteristics, storage behavior, and storage facilities used were analysed using descriptive statistics. T-test and Chi-squared test were used to test for significance in important variables for this study, distinguishing between the regions.

This study used the random utility theory to explain the choices made by an individual farmer between several potato storage technology options [21]. When making a choice, it is assumed that the farmers' preference is driven by the anticipated satisfaction from the choice. Therefore, if the i^{th} farmer from a population n (i = 1, . . . , n) has the option to choose between J storage technology choice combinations, the utility of choice j (j = 1, . . . , J) is expressed as:

$$U_{ij} = X'_{ij}\beta + \varepsilon_{ij} \quad (1)$$

where:

i = the individual household i

j = the different choice combinations of storage technologies (the j^{th} storage technology chosen)
X'_{ij} = the individual household and storage technology characteristics
β = the vector of parameters
ε_{ij} = the error term

If the farmer i chooses storage technology j in particular, we then assume that U_{ij} gives the maximum among the J utilities for the farmer. Hence, the probability that choice j is made from a set of J alternative choice combinations is given as:

$$\text{Prob}\ (U_{ij} > U_{iJ}) \text{ for all other } J \neq j \quad (2)$$

From Equation (2) above, we observe that the utility a farmer obtains varies across individual farmers, implying that the farmer will prefer a particular technology or combination of technologies if the benefits of his or her choice exceed those of the alternatives available [22].

A multinomial probit model was adopted in this study to establish determinants of the choice of storage technologies. An alternative model that could have been used to answer this question is the multinomial logit model. However, results from the multinomial logit model would not be valid if a household takes up more than one of the analysed technologies and therefore belongs to more than one analysed category. The multinomial probit model relaxes this independence restriction ("independence of irrelevant alternatives" (IIA)) in the multinomial logit model [23]. The multinomial probit model also allows for possible interaction among the unobserved characteristics in the choice equations, as well as the relationships between the choices of different storage technology combinations [24].

The multinomial probit model comprises the choice set of all possible combinations of storage technologies. Four technologies and their combinations were used: light space in the house (LSH), dark space in the house (DSH), light space outside the house (LS) and dark space outside the house (DS). As shown in Table 1, these four storage technologies could generate 16 possible combinations of choices from which the i^{th} farmer can choose. Based on this choice set, the multinomial probit model was estimated as follows:

$$y^*_{ij} = X'_{ij}\beta_j + \varepsilon_{ij}\ j = 1, \ldots, J \quad (3)$$

Table 1. Possible storage technology choice combinations.

Number	Possible Technology Choice Combinations
1	Household uses none of the storage technologies of focus in the study
2	Household uses LSH only
3	Household uses DSH only
4	Household uses LS only
5	Household uses DS only
6	Household uses LSH and DSH
7	Household uses LSH and LS
8	Household uses LSH and DS
9	Household uses DSH and LS
10	Household uses DSH and DS
11	Household uses LS and DS
12	Household uses LSH, DSH and LS
13	Household uses LSH, DSH and DS
14	Household uses LSH, LS and DS
15	Household uses DSH, LS and DS
16	Household uses all four storage technologies

We assume that y^*_{ij} is composed of both the observed characteristics that influence the choice of a storage technology combination and the unobserved characteristics captured

by the stochastic error term ε_{ij}. ε_{ij} follows a multivariate normal distribution, each with a mean of zero and a covariance matrix of unobserved characteristics ($\sum_{\varepsilon}$). β_j is the vector of unknown parameters to be estimated based on observable binary discrete variables (y_{ij}) that shows whether or not the farmer chooses a particular storage technology combination. The unobserved choices in the model translate into the observed binary outcome equation for each storage technology choice combination as expressed below in Equation (4):

$$y_{ij} = \begin{cases} j \text{ if } \max\left(y_{ij}^{*}\right) \geq 0 \\ 0 \text{ if} \max\left(y_{ij}^{*}\right) < 0 \end{cases} \quad (4)$$

For the j^{th} preferred storage technology/combination of storage technologies, the model is thus represented as follows:

$$y_{ij}^{*} = X_{ij}'B + \varepsilon_{ij} \quad (5)$$

where:

$j = 1, \ldots, J$; $i = 1, \ldots, n$ and $y_{ij} = 0$ represents a base category.

The dependent variables included in the model were the different choices of storage technology category combinations (Table 1). For each choice made, the variable takes on the value 1 and 0 otherwise. One choice category is normalised to zero (base category) [25]. The independent variables include farmer characteristics, such as household size and age, education, and potato farming experience of the household head (Table 2). Other independent variables include access to potato management advice, membership to farmer groups or associations, access to credit, the proportion of land under potato cultivation, other monthly income from farm and off-farm activities, and distance to the market. The expected signs showing the relationship between the choice of storage technology used and the explanatory variables are based on existing literature that can be obtained from [19,20,26–31]. The multinomial probit model also allows the generation of marginal effects of the independent variables with respect to the probability of using one of the storage technology combinations.

Table 2. Variables used in the multinomial probit model and their hypothesized signs.

Variable	Variable Description	Expected Sign
Y_i	Storage technology combinations	
	Household characteristics	
X_1	Age of household head (years)	+
X_2	Education of household head (years)	+/−
X_3	Household size	+/−
	Institutional factors	
X_4	Access to potato management advice (1 = Yes, 0 = No)	+/−
X_5	Membership to farmer group or association (1 = Yes, 0 = No)	+/−
X_6	Access to credit (1 = Yes, 0 = No)	+/−
	Assets	
X_7	Proportion of land under potato cultivation (%)	+/−
X_8	Other monthly income from agriculture and non-agriculture businesses (UGX)	+/−
	Others	
X_9	Distance to market (walking minutes)	−

3. Results

3.1. Socioeconomic Characteristics of Potato Farmers

Table 3 shows the socioeconomic characteristics of the potato farmers surveyed in this study. The age of the household heads was, on average, 43 years, and the overall average size of the household to which the surveyed farmers belong was six people. Households in eastern Uganda (6) have on average one member more than those in the southwestern region (5), though their heads are significantly younger ($p < 0.01$). Almost

two-thirds (64%) of the sampled respondents belonged to male-headed households. On average, the household heads had completed six years of formal education, with the ones in eastern Uganda having significantly longer ($p < 0.01$) formal education but significantly less ($p < 0.01$) potato farming and storage experience than those in southwestern Uganda. Each household owned, on average, 1 ha of land.

Table 3. Socioeconomic characteristics of the sampled potato farmers.

Socioeconomic Characteristics	Overall (n = 240)	Eastern Region (n = 120)	Southwestern Region (n = 120)	t-Value
		Mean and Standard error		
Age of household head (years)	43.183 (0.962)	38.933 (1.158)	47.433 (1.438)	−4.603 ***
Education level of household head (years in school)	5.771 (0.252)	6.892 (0.314)	4.650 (0.369)	4.625 ***
Household size (number of members)	5.817 (0.163)	6.333 (0.234)	5.300 (0.217)	3.241 ***
Potato farming experience of household head (years)	15.438 (0.854)	10.858 (0.965)	20.017 (1.283)	−5.706 ***
Potato storage experience of household head (years)	13.554 (0.833)	8.200 (0.826)	18.908 (1.275)	−7.048 ***
Total land owned (ha)	0.927 (0.079)	1.001 (0.088)	0.853 (0.131)	0.942
Total annual potato harvest (kg)	5436.917 (590.775)	9069.500 (1072.132)	1804.333 (175.168)	6.688 ***
Annual potato yield (t/ha)	11.905 (1.011)	16.793 (1.591)	7.017 (0.769)	8.777 ***
Total land under potato cultivation (ha)	0.465 (0.046)	0.610 (0.082)	0.319 (0.038)	3.229 ***
		Percentage		Chi-squared Value
Gender of household head (male)	64.170	65.830	62.500	0.290
Access to credit (yes)	60.000	47.500	72.500	15.620 **
Access to potato storage management advice (yes)	20.000	32.500	7.500	3.278
Membership to farmer group (yes)	35.000	45.000	25.000	10.550 **
Access to market information (yes)	72.080	89.170	55.000	34.810 ***

Note: Figures in parentheses represent standard errors, while *** and ** denote significance levels at 1% and 5%, respectively.

The surveyed farmers harvest annually 5 t of potato on average, although farmers in eastern Uganda harvest significantly more ($p < 0.01$) potato (9 t) compared with those in southwestern Uganda (2 t). There was significantly higher productivity ($p < 0.01$) in the eastern region (17 t/ha) compared with southwestern Uganda (7 t/ha). The area under potato cultivation per farmer was also significantly higher ($p < 0.01$) in eastern Uganda (0.6 ha) than in southwestern Uganda (0.3 ha).

Only a minority of the potato farmers in eastern and southwestern Uganda had access to advice on potato storage management. However, a small majority of them had access to credit with signification difference ($p < 0.05$) between the two regions. Significantly more ($p < 0.05$) potato farmers in eastern Uganda (45%) were members of a farmer group or association compared with their counterparts in the southwestern region (25%). Moreover, potato farmers in eastern Uganda had significantly better ($p < 0.01$) access to market information than those in southwestern Uganda. Information on potato market price and possible buyers was the most important market information obtained by the farmers. Other less frequently obtained market information was, in decreasing order of importance, information on market demand, product requirements, market trends, possible suppliers, and market channels. The leading sources of market information were individual fellow farmers and potato traders.

3.2. Storage Behavior of Potato Farmers

Table 4 gives an overview of the potato storage behavior of the surveyed farmers and their households. Almost all potato farmer households store potato for later consumption as food at home (94%), with no significant difference between male- and female headed households. Depending on the season, potato stored at home for food is stocked for a period of 1.5—2 months. Potato storage as seed for own planting during the following season was carried out by a large majority of the surveyed farmers, although significantly more ($p < 0.1$) male-headed households in southwestern Uganda (93%) store potato as farm-saved seed. Potato stored for seed is kept for a period of three months; this is the time between harvest and planting, with the latter depending on the start of the rainy season. Storage of potato as seed for later sale and ware for gifts were generally done by a smaller

proportion of the farmers. Storage of ware potato for later sale was the least reported storage purpose, performed by only 3% of the surveyed farmers. The profitability of the activity and the availability of a storage facility were their main drivers. The few farmers who stored ware potato for later sale reported a mean storage duration of 75 and 60 days in season 2017 B and 2018 A, respectively. There was no storage of ware potato for sale during the off-season in both regions.

Table 4. Purpose of potato storage by farmers.

	Overall (%)		Eastern Region (%)		Southwestern Region (%)	
Storage Behavior	**Male-Headed Households (*n* = 154)**	**Female-Headed Households (*n* = 86)**	**Male-Headed Households (*n* = 79)**	**Female-Headed Households (*n* = 41)**	**Male-Headed Households (*n* = 75)**	**Female-Headed Households (*n* = 45)**
Storage for food at home	92.208	96.512	91.139	97.561	93.333	95.556
Storage for seed for own planting	85.714	80.233	78.481	78.049	93.333 *	82.222
Storage for seed for sale	5.844	5.814	6.329	7.317	5.333	4.444
Storage for ware for gifts	18.182	18.605	24.051	17.073	12.000	20.000
Storage for ware for sale	3.896	1.163	3.797	2.439	4.000	0.000

Note: * denotes significance levels at 10%.

When analyzing the use of the total volume of harvested potato by the surveyed farmers (Table 5), most of the production is sold fresh immediately after harvest (60%), mainly at the farmgate or in nearby rural markets, with more males ($p < 0.05$) selling fresh potato (62%) compared with females (56%). Additionally, 13% and 16% were stored for food at home and seed for own planting, respectively. However, significantly ($p < 0.01$) more females (17%) stored for food at home than males (11%). Furthermore, 6% was lost at harvest, while only 0.4% was stored as ware potato for later sale.

Table 5. Use of harvested potato by farmers.

	Overall (%)		Eastern Region (%)		Southwestern Region (%)	
Potato Use	**Male-Headed Households (*n* = 154)**	**Female-Headed Households (*n* = 86)**	**Male-Headed Households (*n* = 79)**	**Female-Headed Households (*n* = 41)**	**Male-Headed Households (*n* = 75)**	**Female-Headed Households (*n* = 45)**
% lost after harvest	5.921	6.871	5.017	4.558	6.874	8.979
% paid to workers after harvest	3.078 *	2.137	4.538	3.701	1.540	0.711
% sold fresh after harvest	62.351 **	55.962	75.261	69.734	48.753	43.414
% stored for food at home	11.252 ***	17.243	4.758	9.966	18.094	23.874
% stored for seed for own planting	15.827	15.402	8.534	10.570	23.509	19.805
% stored for seed for sale	0.367	0.447	0.432	0.459	0.298	0.435
% stored for ware for gifts	0.638 *	1.846	0.493	0.821	0.790	2.781
% stored for ware for sale	0.566	0.092	0.967	0.192	0.143	0.000

Note: ***, ** and * denote significance levels at 1%, 5% and 10%, respectively.

3.3. Storage Facilities Used by Potato Farmers

Results in Table 6 indicate light store and light room in the house as the primary storage facilities used by potato farmers. The light store was significantly more ($p < 0.01$) used in the southwestern region (39%) compared with the eastern region (14%). In both regions, the light stores were mainly located on the farm, as reported by 68% and 94% of the respondents in the southwestern and eastern regions, respectively. Most of these light stores were owned by farmer households (98% in southwestern Uganda, 94% in eastern Uganda). Only a few light stores were individually rented (3%) or individually borrowed (6%). The light room in the house was used by a significantly higher number ($p < 0.01$) of potato farmers in eastern Uganda (55%) compared with the southwestern region (22%). Other storage facilities used to a lesser extent by potato farmers include kitchen (16%), living room (13%), dark room in the house (12%), granary covered with mud (5%), dark store (7%), bedroom (1%), and granary not covered with mud (1%) (Figure 1).

Table 6. Storage facilities used by the sampled potato farmers.

Main Storage Facility	Overall (%) (n = 240)	Eastern Region (%) (n = 120)	Southwestern Region (%) (n = 120)	Chi-Squared Value
Light room in the house	38.330	55.000	21.670	11.818 ***
Light store	26.670	14.170	39.170	31.280 ***
Kitchen	16.250	22.500	10.000	2.711
Living room	13.330	18.330	8.330	1.996
Dark room in the house	11.670	12.500	10.830	0.157
Dark store	7.080	1.670	12.500	15.150 ***
Granary covered with mud	5.000	9.170	0.830	5.900
Bedroom	1.250	2.500	0.000	2.278
Granary not covered with mud	0.830	1.670	0.000	1.514

Note: *** denotes significance levels at 1%.

Figure 1. Traditional storage facilities used by potato farmers in eastern and southwestern Uganda (from left to right: light store, dark store, granary covered with mud, granary not covered with mud) (Credit: CIP/P. Wauters).

This study shows that 'affordability', 'safe from theft/disturbance' and 'maintains the quality of the potato stored' are in decreasing order of importance as the overall main reasons potato farmers opt for a specific storage facility (Table 7). Their relative importance, however, varies among the different storage facilities. 'Affordability' is a more important reason for choosing light store and light room in the house compared with dark store and dark room in the house. Light storage facilities are indeed less expensive to construct than dark storage facilities. Furthermore, 'easy sprouting' is also one of the main reasons for choosing a light store.

3.4. Factors Influencing the Choice of Storage Technologies by Potato Farmers

For meaningful analysis and to improve on the subsamples of the surveyed potato farmers, the reported storage technologies were combined into four major technologies. First, the dark room in the house and bedroom were combined to form 'dark space in the house' (DSH). Secondly, the dark store and the granary covered with mud were combined into 'dark space outside the house' (DS). The third combination (light space in the house, LSH) was composed of a light room in the house, kitchen, and living room. Lastly, the light store and granary not covered with mud were combined to form the light space outside the house (LS). The different combinations observed after grouping into these four major storage technologies are: use none of the storage technologies, use of LSH, use of DSH, use of DS, use of LS, use of LSH and DSH, use of LSH and DS, use of LSH and LS, use of DSH and LS, and use of DS and LS (Table 8). However, the first combination (use none of the storage technologies) was dropped because there was no choice of any storage technology made by 1% of the potato farmers, meaning they did not store potato at all. This implies that they could not be included in the multinomial probit model. Because of the low frequencies, all observations with combinations of two different spaces were combined to form one category (use of two storage spaces). In estimating the multinomial probit model, a total of five choice categories were thus used: LSH, DSH, DS, LS, and a combination of two storage spaces. These categories were used because they reflect best the reality of storage technologies used by farmers in the study area. (Table 9). To run the multinomial probit model, the combination of two storage spaces was used as the base category.

Table 7. Main reasons storage facilities used by potato farmers.

Main Reason	Dark Store (%) (*n* = 17)	Light Store (%) (*n* = 64)	Granary Covered (%) with Mud (*n* = 12)	Dark Room in the House (%) (*n* = 28)	Light Room in the House (%) (*n* = 92)	Living Room (%) (*n* = 32)	Bedroom (%) (*n* = 3)	Kitchen (%) (*n* = 39)	Granary Not Covered with Mud (%) (*n* = 2)	Total (%)
Affordable	10.81	13.02	17.65	10.81	19.43	25.15	13.33	22.71	33.33	17.70
Safe from theft/disturbance	27.03	13.61	5.88	18.24	18.12	17.79	13.33	7.73	11.11	15.41
Maintains the quality of the potato stored	10.81	17.75	19.12	22.30	12.66	8.59	40.00	2.90	0.00	13.38
Do not have a separate store	4.05	8.28	1.94	14.86	8.52	13.50	33.33	9.66	0.00	9.53
Easy to monitor/manage the stored potato	8.11	4.44	1.47	7.43	9.83	11.66	0.00	16.91	0.00	8.92
Construction materials found locally	2.70	10.36	19.12	2.03	5.68	1.84	0.00	7.73	0.00	6.62
Easy sprouting	4.05	10.36	8.82	7.43	5.90	1.23	0.00	4.35	55.56	6.62
Easy to build	8.11	6.51	19.12	0.68	4.59	2.45	0.00	10.14	0.00	5.95
Easy access to potato	2.70	4.73	0.00	7.43	3.28	9.20	0.00	8.70	0.00	5.20
Easy to maintain	0.00	5.92	4.41	2.70	4.15	6.13	0.00	5.31	0.00	4.53
Adapted to the potato volume to store	12.16	3.85	1.47	3.38	5.24	1.23	0.00	1.45	0.00	3.85
Don't know other types of potato storage facilities	4.05	1.18	0.00	0.68	1.97	0.00	0.00	1.45	0.00	1.35
Have a separate store but too small	5.41	0.00	0.00	2.03	0.66	1.23	0.00	0.97	0.00	0.95

Table 8. Proportion of potato farmers using different storage technology combinations.

Storage Technology Combinations	Number of Farmer Households (n = 240)	Percentage (%)
LSH	119	49.583
LS	48	20.000
DSH	21	8.750
DS	19	7.917
LSH and LS	13	5.417
LSH and DS	8	3.333
LSH and DSH	4	1.667
Use none of the storage technologies	3	1.250
DSH and LS	3	1.250
DS and LS	2	0.833

Table 9. Storage technology combinations included in the multinomial probit model.

Storage Technology Choices	Frequency (n = 237)	Percentage (%)
LSH	119	50.211
LS	48	20.253
Combination of two spaces	30	12.658
DSH	21	8.861
DS	19	8.017

Results from the analysis of factors affecting the choice of storage technologies using the multinomial probit model are presented in Table 10. The Wald test showed that the model is significant, and therefore we reject the hypothesis that all coefficients in each equation are equal to zero. A correlation test for multicollinearity was also performed for the explanatory variables used in the model, and we observed that the independent variables used in the model were not strongly related to each other. The relationship was between 0.17% and 47.04%.

Results indicate that potato farmers with more household members were significantly ($p < 0.05$) less likely to use light space outside the house for potato storage. Analysis indicated that an increase in household size by one additional member reduced the likelihood of using the light space outside the house by potato farmers by 3%, holding all other factors constant.

Potato farmers located near markets were significantly less likely ($p < 0.05$) to use dark space in the house to store potato by 4% and significantly more likely ($p < 0.05$) to use light space in the house by 6%.

The proportion of land under potato cultivation has significantly improved the probability of potato farmers using light space outside the house ($p < 0.01$) by 12% and significantly reduced the probability of using light space in the house ($p < 0.01$) by 18%.

Potato farmers who had monthly income sources other than income from potato sales were significantly ($p < 0.05$) more likely to use a combination of two spaces for potato storage by 5%.

A unit increase in the number of potato farmers accessing potato storage management advice increased significantly ($p < 0.05$) the probability by 16% that they used a combination of two storage spaces.

Access to credit was another important factor determining the choice of storage technologies. Potato farmers who had access to credit were significantly more likely to choose the dark space in the house ($p < 0.05$) and dark space outside the house ($p < 0.05$) for potato storage by 9% and 7%, respectively. They were also less likely to choose the light space in the house ($p < 0.05$) by 15%.

Table 10. Factors influencing the choice of storage technologies by potato farmers.

Variable	Light Space in the House (*n* = 119)	Dark Space in the House (*n* = 21)	Light Space outside the House (*n* = 48)	Dark Space outside the House (*n* = 19)	Combination of Two Spaces (*n* = 30)
Household characteristics			Marginal effects		
Age of household head (years)	−0.002 (0.003)	0.000 (0.002)	0.000 (0.002)	0.001 (0.001)	0.001 (0.002)
Education level of household head (years in school)	0.009 (0.012)	−0.008 (0.007)	−0.001 (0.009)	0.004 (0.006)	−0.003 (0.008)
Household size (number of members)	0.018 (0.016)	0.012 (0.009)	−0.025 ** (0.013)	−0.002 (0.009)	−0.002 (0.010)
Institutional factors					
Access to potato storage management advice (1 = Yes, 0 = No)	−0.074 (0.093)	0.014 (0.056)	−0.077 (0.063)	−0.019 (0.044)	0.156 ** (0.077)
Membership to farmer group or association (1 = Yes, 0 = No)	−0.029 (0.077)	−0.038 (0.042)	0.029 (0.059)	0.027 (0.041)	0.012 (0.052)
Access to credit in the previous 12 months (1 = Yes, 0 = No)	−0.154 ** (0.074)	0.085 ** (0.040)	−0.074 (0.054)	0.073 ** (0.037)	−0.078 (0.052)
Assets					
Proportion of land under potato cultivation (%)	−0.184 *** (0.071)	−0.005 (0.038)	0.120 *** (0.044)	0.017 (0.033)	0.052 (0.044)
Monthly income from other sources (UGX)	−0.033 (0.029)	0.001 (0.016)	−0.021 (0.021)	0.005 (0.015)	0.048 ** (0.019)
Others					
Distance from the homestead to the market (walking minutes)	0.062 ** (0.037)	−0.041 ** (0.019)	−0.037 (0.027)	0.001 (0.020)	0.015 (0.026)

Likelihood = −250.67673: Wald Chi^2 (40) = 62.62 and Prob > Chi^2 = 0.0126. Figures in parentheses are standard errors while *** and ** denote significance levels at the 1 and 5%, respectively.

4. Discussion

4.1. Socioeconomic Characteristics of Potato Farmers

Smallholder potato farmers in the highland areas of Uganda owned on average 1 ha of land. This suggests that there has been a reduction of 34% in the total land owned by farming households in Mbale and Kabale compared with 2014 data [7]. Population growth is the primary driver of land fragmentation, whereby poor households continue to subdivide ancestral farmlands leading to smaller individual plots [32]. Though not significantly, households in eastern Uganda own more land compared with those in the southwestern region, suggesting a higher population pressure on the available arable land in the latter.

The differences in potato production between the regions can be explained by significantly higher productivity ($p < 0.01$) in the eastern region (17 t/ha) compared with southwestern Uganda (7 t/ha). This difference in productivity is probably because much land planted in Kween district in eastern Uganda is newly cultivated, hence more productive compared with the land in southwestern Uganda, which is heavily affected by overcultivation and land degradation, including erosion. In addition, low potato yields in southwestern Uganda are due to low uptake of quality inputs like fertilizer, seed, and pesticides [33]. The yields obtained in this study are, however, much higher than those reported by the Uganda Bureau of Statistics for the year 2018 (eastern Uganda: 4 t/ha; southwestern Uganda: 3 t/ha) [34]. The area under potato cultivation is also significantly higher ($p < 0.01$) in eastern Uganda (0.6 ha) than in southwestern Uganda (0.3 ha), which further explains the differences in potato output between the two regions.

Farmers organized in groups or associations are better placed and empowered to access essential services such as extension, credit, and market information, among others [1,19]. This most likely explains why more farmers in eastern Uganda (33%) have access to potato storage management advice compared with southwestern Uganda (8%), and significantly more ($p < 0.01$) potato farmers in the eastern region (89%) have access to market information compared with the southwestern region (55%). Contrary to what one would expect, potato farmers in southwestern Uganda (73%) have significantly better access to credit ($p < 0.05$) compared with their counterparts in the eastern region (48%). Similarly, more than three-quarters of the potato farmers in the districts of Kisoro and Kanungu had access to credit [35].

4.2. Storage Behavior of Potato Farmers

Potato farmers sell most of their production immediately after harvest. This result affirms that potato is an important cash crop in the highlands of eastern and southwestern Uganda. Results of this study also show that the majority of potato farmer households store potato for later consumption as food at home, confirming that potato is an important food crop in the study area. Potato is a vegetative propagated crop. Table 4 shows that most farmers store seed for their own planting, confirming that most Ugandan farmers recycle their own seed. This study also shows that there was no storage of ware potato for sale during the off-season in Uganda. This is most probably because of the high prices that farmers can obtain from potato sales immediately after harvest during this time of the year.

In general, Ugandan potato farmers do not store potato as a ware potato for later sale. This result is in line with available literature [36]. This lack of ware potato storage for later sale results in seasonal mismatches between potato demand and supply, leading to high price fluctuations. During harvest, excess supply of potato leads to low farm gate prices, while in other times of the year, when the potato is still in the field, supply shortages increase market prices drastically. This situation is similar in other African countries. In Kenya, for example, the majority of the potato farmers sell most of their produce at the farm gate leading to clear seasonal peaks in the supply of potato to local and urban markets. As a result, price fluctuations in potato can be extremely high within a period of 2–3 months, with prices increasing by up to three times the price at harvest [37].

4.3. Storage Facilities Used by Potato Farmers

Light store and light room in the house were the primary storage facilities used by potato farmers. These results contradict the findings of other authors [14], who found that dark stores were more commonly used than light stores in eastern Uganda. There are, however, some significant differences in the types of storage facilities used between the regions. For this reason, it is important to note that the use of storage facilities is determined by factors like climate, the reason for the storage of tubers, and sociocultural aspects of storage [3]. Farmers in Kenya also store potato mainly in stores that allow light, followed by dark stores, wooden floors, and other storage facilities. This is probably because their main purposes of storing potato are, in decreasing order of importance, storage for seed, home consumption, and waiting for better prices [36].

Besides 'maintains the quality of the potato stored', 'safe from theft/disturbance' and 'affordability', 'easy sprouting' is also one of the main reasons why potato farmers use a light store. This can be explained because half of the potato stored by farmers is stored as seed for the next season, and light allows tubers to sprout. While this characteristic is beneficial for the ones storing tubers as seed, it can drastically affect the ability to keep the tubers long enough for those farmers willing to store ware potatoes for later sale at a higher price. 'Safe from theft/disturbance' and 'maintains the quality of the potato stored' seem to be more important reasons for choosing dark store and dark room in the house than light store and light room in the house. This is probably because darkness makes the stored potato less visible and reduces quality loss during storage due to greening and sprouting.

4.4. Factors Influencing the Choice of Storage Technologies by Farmers

Farmers with bigger households are less likely to use light space outside the house. This is probably because bigger households in rural farming communities consume quicker and more quantities of potato at home, and therefore space in the house is more convenient for storage of potato for food preparation at home. They usually also spend more income on household needs rather than save to invest in storage space separate from the residential house compared to smaller households. Other studies [38,39] also found that farmers with bigger households spent more money on food, daily household needs and used less expensive stores than those with smaller households.

Potato farmers located near markets were significantly less likely to use dark space in the house to store potato and significantly more likely to use light space in the house. Farmers who have readily available markets may not have the incentive to invest in long term ware potato storage due to the lure of readily available cash from the sales of freshly harvested potato and the possibility of avoiding storage costs. These nearby potato markets also provide easy accessibility to potato for food to consume at home, thus possibly discouraging potato storage for food. Where little or no potato is stored for home consumption or later sale as ware, no strict quality criteria are applicable, so farmers use light spaces that are more convenient to manage. Previous studies, however, document the contribution of market access to the improvement of potato postharvest handling because farmers fetch higher prices from the sales of value-added ware potato [1,7,19]. Longer distance to the market by farming households has also been associated with less market orientation in production decisions, leading to low marketable surpluses for storage [19].

The proportion of land under potato cultivation has significantly improved the probability of potato farmers using light space outside the house and significantly reduced the probability of using light space in the house. Light spaces outside the house in the study area had a storage capacity of 3–6 t compared with the 2–3 t storage capacity of light spaces in the house. A more significant proportion of land allocated to the potato is likely to translate into the need for more storage space of potato as seed for own planting. Likewise, a similar study in Nigeria [40] noted that farmers with a higher proportion of land under potato production are more likely to adopt improved storage techniques when compared with those with a smaller proportion of land under potato production.

Potato farmers who had monthly income sources other than income from potato sales were significantly more likely to use a combination of two spaces for potato storage. This is expected because producers with monthly income from other sources are likely to have the financial resources to invest in the construction and management of two different storage spaces. This observation, however, differs from the findings of earlier studies [1,41], which argue that off-farm monthly income limits the improvement of postharvest management practices and the uptake of modern technologies by farmers. According to the authors, farmers who earn higher off-farm income are more likely to dedicate less time to good postharvest handling of their crops.

Potato farmers accessing potato storage management advice use significantly more a combination of two storage spaces. A possible reason for this is that potato farmers with better access to potato storage management advice are knowledgeable in different types of storage technologies and their benefits on potato stored for different uses. Therefore, they are more likely to use two different types of storage spaces such that the space for seed potato is different from the space for ware potato. Furthermore, access to extension services positively influences potato value addition due to increased knowledge of farmers on postharvest handling [1].

Potato farmers who had access to credit were significantly more likely to choose the dark spaces in and outside the house for potato storage. They also were significantly less likely to choose the light space in the house. This is likely because light storage spaces are considered inexpensive to build and manage. Access to credit thus allows potato farmers to invest in the more expensive dark storage spaces inside and outside the house. This

result differs, however, from the findings of other studies [1,42] indicating a negative effect of access to credit on the utilization of recommended postharvest techniques.

5. Conclusions

Findings from this study confirm the general idea that potato is an important food and cash crop in the highlands of eastern and southwestern Uganda. Potato farmers sell a majority (60%) of their production immediately after harvest, while the remainder is stored primarily for food at home (13%) or as seed for the next season (16%). Very few farmers (0.4%) store potato as ware potato for later sale and thus miss the opportunity to increase their income by exploiting the seasonal market price fluctuations. This study also shows that light room in the house and light store are the main storage facilities used by Ugandan potato farmers. In a decreasing order of importance, kitchen, living room, dark room in the house, dark store, granary covered with mud, bedroom, and granary not covered with mud are other storage facilities used to a lesser extent by potato farmers. Light storage conditions are suitable for seed as they promote sprouting, however, storage of ware potato requires dark storage conditions.

Overall, 'affordability', 'safe from theft/disturbance' and 'maintains the quality of the potato stored' are the main reasons potato farmers opt for a specific storage facility, yet, their relative importance varies among the different storage facilities. Monthly income from sources other than potato sales and access to potato storage management advice are factors significantly and positively affecting the use of a combination of two storage spaces. Furthermore, access to credit influenced significantly and positively the use of dark spaces inside and outside the house. These results suggest that enhancing access to adequate extension services and credit are critical to improve the storage conditions of ware potato stored for food at home or for later sale by farmers in Uganda. Currently, a small majority of potato farmers (60%) has access to credit, while only a minority has access to advice on good potato storage practices (20%). When promoting ware potato storage technologies in Uganda, however, there is also a need to ensure that these technologies are affordable to farmers and provide adequate protection of the tubers against theft or disturbance.

This study, however, has two limitations. First, although potato is also produced in the highlands of western Uganda, the midlands of northwestern Uganda and the lowlands of central Uganda, the study area was limited only to the two major production areas in the highlands of southwestern and eastern Uganda. Furthermore, the small sample sizes due to the limited population compromise the robustness of the results. This especially applies in cases where it was not possible to sample more stores because the entire population was sampled. More research in other potato producing areas in Uganda and with bigger sample sizes is thus required. Also, the examination of the farmers' perceptions of the different storage technologies used is highly recommended.

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