Influence of Information and Crop Management Practices on Productivity among Smallholder Potato Farmers in North Rift Kenya

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Abstract

Potato (Solanum tuberosum L) tuber, is a major food whose demand is increasing worldwide. Its value-chain in Kenya generates employment for approximately 800,000 farmers and 3.3M citizens. Nonetheless, in spite of dissemination of appropriate technologies, innovations, and management practices (TIMPs), Kenya's productivity has persisted at lows of 9-15t/Ha compared to Netherland's 36-42t/Ha. Implementation of field-specific decision support system (DSS) has been proposed as a possible intervention. However, no studies exist showing the influence of prevailing information management (IM) practices on crop management practices. Therefore, in the context of precision agriculture (PA) and the theory of the firm, this study sought to assess, subject to farming duration, the influence of information sources on crop spacing and resultant effect on productivity among smallholder potato farmers in Kenya's North-Rift highlands. Using stratified random sampling, a survey was conducted on 353 households of whom potato was the main crop and whose farms were located at least 2300masl. Descriptive statistics, linear regression and post-estimation data analysis techniques were employed. Extension services, radio, farmer groups, Internet and telephone usage stood at 62%, 45%, 18%, 6% and 3% respectively while 11% possessed an email address. Regardless of farming duration, in decreasing order, radio and Internet (implicitly) showed positive aggregate influence while farmer groups and extension services showed negative aggregate influence. Notably, all information sources were significantly associated with 'not known' seed spacing response with corresponding significant negative effect on productivity. The results demonstrate poor IM and imprecise crop management practices thereby validating the necessity for entrenchment field-specific DSS.

Keywords: Precision Agriculture; Smallholder Potato Farming; Socioeconomics; Climate Smart Agriculture

INTRODUCTION

Potato (*Solanum tuberosum L*) tuber, being one of the key ingredients for fast food, serves as an important crop whose demand is continuously increasing worldwide: according to projection data for the period 2012 – 2030, worldwide demand of potato as a food source will increase by 27% (FAO, 2018). In addition, the potato value-chain in Kenya generates employment for approximately 3.3 million people and 800,000 farmers (MoALF, 2016).

FAO (2020) country/ region productivity (t/Ha) data, sampled for the year 2019, provides the following: North America (47.3), Netherlands (42), Egypt (28), India (23), Caribbean (20), China (18), Africa (15), East Africa (15), and Kenya (9.3). For the study location, productivity for Uasin Gishu County stood at 11.2t/Ha in 2016.while that for Elgeyo Marakwet County was 19t/Ha in 2015 (MoALF, 2018). In their study, Wang'ombe & Djik

(2013) observed maximum yield of over 33 t/Ha therby providing a pragmatic potential yield for Kenya.

A snapshot of intricacies of evolution of potato productivity is depicted by Vos (1992) in an extensive review of over 100 years' potato production in Netherlands. The observation that, in the early segment of that period, yields had stagnated at 10-15t/Ha is strikingly similar to the prevailing persistent 9-15t/Ha in Kenya. It took Netherlands 40 years (from 1950) for yields to improve to the current 42t/Ha. The breaking of the productivity ceiling is attributed to adoption of technologies innovations and management practices (TIMPs) including: selection and breeding; improved storage; seed certification; improved crop nutrition; and chemical controls among others. Of significance to this study was the critical necessity for precise implementation of the TIMPs aided by enhanced crop monitoring as well as production data collection and analysis. In this regard, the use of field-specific decision support system (DSS) based on knowledge of the TIMPs was key. Such DSS would provide a rational basis for objective and effective decision making. From studies on TIMPs adoption in Kenya, Amara et al., (1999) conclude that, among other factors, innovative institutional arrangements (extension services techniques) that enhance extension and farmer training are likely to enhance potato productivity. Obare et al., (2010), established that the higher the experience of the farmer the more likely that inputs will be applied in an optimal manner. Wang'ombe & Djik (2013) demonstrated that despite high levels of awareness and adoption, there is further need for precision in the implementation of the adopted TIMPs as well as use of innovative knowledge dissemination techniques in order to overcome the low productivity ceiling.

In economic terms, according to Malmgren (1961), the ultimate objective of any firm is to reduce the effect of information uncertainty and attain stability in both production and prices. Malmgren termed this stability as "expectational equilibrium" and stated that such a stability can only result from controlling information in a manner that causes reduction in costs of information discovery. In the absence of precise production function, controlled information enables predictability of events over an entire production cycle. This results in better control of the production plan covering the set of all activities up to the requisite profit horizon. Disruptions in the "expectational equilibrium" can occur under three conditions: when entrepreneurs use too little information of that which is readily available; or use incorrect information; or random events occur that renders the expectations as incorrect. In addition, time limitations further restrict the amount of information available for decision-making. In this regard, it therefore is necessary to establish a consistent decision-making and communication mechanism.

Based on discussion by Stafford (2000), McBratney et al. (2005) and Zhang et al., (2002), this study views precision agriculture (PA) as one such innovative information dissemination mechanism that encompasses the use of a field-specific DSS as part of its IM practice. This aspect of DSS in PA is further corroborated by Taechatanasat & Armstrong (2014), Arnott & Pervan (2005), Mansouri et al. (2012) and Turban et al. (2005). The problem of persistent low potato productivity in Kenya pre-supposes existence of sub-optimal "expectational equilibria" (Malmgren 1961) not only due to too little and/ or incorrect information as corroborated by Baba & HakimZadeh (2012), but also due to high cost of information discovery (CID) as argued by Malmgren. It follows therefore that one possible innovative remedy is the incorporation of a DSS into the smallholder potato farming (SPF) enterprise. This can be achieved through employment of precision agriculture (PA) of which DSS is a key component driving the information management (IM) practice.

In the context of SPF in a developing country, this study envisages this PA will be based on non-mechanized PA (nm-PA) practices namely: 1) small management zones (MZ); 2) manual spatial/ temporal variability management (VM); and 3) information management (IM) using a paper-based DSS with human data collection. These nm-PA practices are to be integrated into the traditional potato production process (PP) comprising pre-cultivation, land preparation, crop establishment, maintenance, harvesting, and sale activities. This integration would realize what this study terms as, Precision Agriculture Production Process (PAPP). The core driver of the PAPP will be the field-specific DSS that will provide not only the knowledge-base of requisite TIMPs but also a mechanism for collection of production activities' data. It is expected that this will result in objective, site-specific, factual-based production planning and decision making.

However, one impediment to implementation of PAPP is the absence of literature on prevailing PA practices in SPF in the location of study. This study therefore sought to investigate the influence of innate IM practice on the effect VM practice on yield. Specifically, the study first sought to assess the influence of the prevailing sources of information (S.Inf), on the choice of crop spacing (CS) and its effect on productivity subject to a farmer's farming duration (FD). In addition, the study sought to assess the extent of recording of crop production and monitoring data.

MATERIALS AND METHODS

Study Location

A survey was conducted in March and April 2022 in Uasin Gishu County (Ainabkoi & Kesses Sub-counties) and Elgeyo Marakwet County (Keiyo South & Marakwet West Sub-counties). These are highland regions characterized by ideal conditions for potato cultivation vis-à-vis: deep brown loam soils; reliable average annual rainfall of 600mm-1700mm with two peaks in May and August; and average temperatures of 7^0C-22^0C. The average landholding is estimated at 1.36-2.91Ha (Country Government of Uasin Gishu, 2018) and (County Government of Elgeyo Marakwet, 2018).

Sampling

Multi-stage stratified random sampling technique was employed. The target population was derived from farmers registered in 2021 under a project on integrated weather and market information system by Kenya Agricultural and Livestock Research Organization (KALRO). This unpublished project was by funded by Kenya Climate-smart Agriculture Project (KCSAP) and covered 24 Counties. First, the two counties were purposively selected from those approved for the North-Rift region based on the high significance they attached to potato value chain. Subsequently, selection was made of households that indicated potato as the main farming crop. An altitude restriction of 2300-3000masl was then enforced thereby purposively sampling the four Sub-counties, This resulted in a sampling frame of 3,038 households. Yamane (1967) formula (see equation 1) was then employed, with the margin of error set at 5%, yielding a sample size of 353 (see equation 2).

$$n = \frac{N}{1 + N(e)^2} \qquad \textbf{(1)}$$

n – Sample Size
N – Population
e – Margin of Error

$$n = \frac{3038}{1 + 3038\,(0.05)^2} = \mathbf{353} \qquad \textbf{(2)}$$

Proportionate allocation technique was then applied to derive the sample size for each Sub-county as follows: for Uasin-Gishu Country: Ainabkoi – 105 and Kesses – 115; while for Elgeyo Marakwet County: Keiyo South – 104 and Marakwet West – 29. In order to ensure even distribution, proportionate allocation technique was applied once more to derive the sample size per Sub-location. Finally simple random sampling was applied, using Microsoft Excel data analysis tool, to randomly select individual participating households. Where a sampled farmer could not be reached or did not wish to participate, another one in the same locality was substituted.

Data

The survey collected data on socioeconomic characteristics and potato production practices for the year 2020 and 2021. Annual duration was chosen deliberately to reveal implementation of precision agriculture (PA) practices, especially management zone (MZ). In order to elicit the innate PA practices, the data collected was segmented into three: socioeconomic characteristics (SE); variability management (VM) practices; and Information Management (IM) practices. From the data collected, the core data utilized for this paper was restricted to four categorical variables: (1) crop spacing (CS), (2) farming duration (FD); (3) sources of information (S.Inf); and (4) purpose for sourced information (U.Inf). In addition, the yield, a continuous variable, was computed as a function of the number of bags harvested annually (continuous), number of cultivated seasons (categorical), and potato plot size (continuous). Besides these, in the cause of discussion, analysis of additional data became necessary involving: household size (continuous variable computed as sum of number dependants: at home and in primary/secondary/tertiary education institutions); household school fees expenditure (continuous variable computed as a product of the number of dependants and the estimated annual education fee derived from computation based on government subsidy ratios for each educational level as provided by the institute of policy research, KIPPRA (2019)); livestock ownership (categorical variable entailing cattle/ sheep/ poultry); and source of credit (categorical variable entailing: self/family, farmer group, formal cooperative, and bank). Finally, status of recording of production activities' and crop monitoring data were captured as dummy variables.

Model Specification

CS, a VM practice, was chosen deliberately on the basis that its effective implementation is dependent largely on the correct knowledge. This knowledge is attributed to the accessible sources and usage of information as moderated by the experience of the farmer. In this regard, in order to better distinguish Internet usage, possession of email address was included being one of the common Internet services that can elicit broader access to information services through websites. Given that precise crop spacing is expected to have positive effect on productivity, it is therefore possible to measure the influence of the varied sources of information based on the crop spacing applied.

In order to measure this influence, respective dummy variables were generated for the selected categorical variables ('factors'). These were designated by superscript (i), as follows: A) farming duration (FD) factor [$X^i_{e_d}, i = 1..5$]: {<1 year [$X^1_{e_d}$], 1to5 years [$X^2_{e_d}$], 6to10 years [$X^3_{e_d}$], 11to15 years [$X^4_{e_d}$], >15 years [$X^5_{e_d}$]}; B) source of information (S.Inf.) factor [$X^i_{s_1}, i = 1..6$]: {television [$X^2_{s_1}$], radio [$X^1_{s_1}$], telephone [$X^3_{s_1}$], Internet [$X^4_{s_1}$], farmer group [$X^5_{s_1}$], extension services [$X^6_{s_1}$]}; C) main use of information (U.Inf.) factor [$X^i_{s_2}, i = 1..3$]: {best management practices [$X^1_{s_2}$], weather information [$X^2_{s_2}$], market information [$X^3_{s_2}$]}; D) crop spacing (CS) factor [$X^i_{v_s}, i = 1..4$]: {20x50 [$X^1_{v_s}$], 30x75 [$X^2_{v_s}$], other [$X^3_{v_s}$], not known [$X^3_{v_s}$]}; and as part of S.Inf factor, possession of an email address [$X^1_{s_3}$].

CS factor served as the main effect variable. The S.Inf together with U.Inf factors served as the interacting variables while FD factor served as the moderating variable. The object of measurement was the influence of the S.Inf on the choice of CS subject to FD of the farmer while bearing in mind the effect of the chosen CS category on yield.

Based on the Theory of the Firm, the Cobb-Douglas (CD) production function (see equation 3) was used to relate the yield with the variables as warranted by (Bhanumurthy, 2002). As provided by equation 4, this study adopted the CD model of form provided Gujarati & Porter (2009):

CD production function in stochastic form:

$$Y_i = \beta_1 X_{ji}^{\beta_j} e^{\mu_i} \qquad \textbf{(3)}$$

Where: Y_i = Output; $X_{ji}^{\beta_j}$ = Input Vector; μ_i = Stochastic Error Term; e = ln base;

By log-transformation and setting $\ln \beta_1 = \beta_0$ with k being the number of variables;

$$\ln Y_i = \beta_0 + \sum_{j=1}^{k} \beta_j \ln X_{ji} + \mu_i \qquad \textbf{(4)}$$

Equation (2-5), provides the general CD model for the study based on equation 2-4:

$$\ln Y_k = \beta_0 + \sum_{i=1}^{4} \beta_{v_s}^{i} \ln\left(X_{v_s}^{i}\right)_k + \left[\sum_{i=1}^{6} \beta_{s_1}^{i} \ln\left(X_{s_1}^{i}\right)_k + \sum_{i=1}^{3} \beta_{s_2}^{i} \ln\left(X_{s_2}^{i}\right)_k + \beta_{s_3}^{1} X_{s_3}^{1} + \sum_{i=1}^{5} \beta_{e_d}^{i} \ln\left(X_{e_d}^{i}\right)_k\right] + \mu_k \qquad \textbf{(5)}$$

Where for a given farmer-k: Y_k is the yield; $\left(X_{v_s}^{i}\right)_k$ is the crop seed spacing (main effect); $\left(X_{s_1}^{i}\right)_k$ is the information source; $\left(X_{s_2}^{i}\right)_k$ is the main aim for information; and $\left(X_{s_2}^{i}\right)_k$ is the farming duration; while μ_k is the error term, and all $\beta_?^?$ being coefficients.

Data Collection and Analysis

A structured questionnaire was administered via telephone interview with the response data captured using Google Forms online data kit (ODK). The data was accessed and cleaned using Microsoft Excel. Microsoft Access was used to: separate SE, VM, IM data as distinct queries; compute the yield; and define the dummy variables. The resulting data was imported into and analyzed using Stata version 14 based on the model defined by equation (5).

First, descriptive analysis was first undertaken to determine the proportions of the categories under each factor. In addition, to determine the extent of recording of data from select production and crop monitoring activities. Ensuing, correlation analysis results showed compliance with requirement for non-existence of multicollinearity. However, other tests of OLS regression assumptions on the unstandardized residuals showed presence of heteroscedasticity and violation of assumption of normality of residuals. In this regard, robust regression was subsequently employed.

Next, the dummy variables of each of the four factors were regressed separately in order to examine the significance as well as the unstandardized and standardized coefficients of each category. The results obtained were used to eliminate some categories as follows: 1) from the CS factor, 'Other (Othr)' category was eliminated in favor of 'not known (NK)' due to their relatively close correlation and also due to 'NK' having a much higher standardized coefficient; 2) similarly, from the S.Inf factor, ' television (TV)' was dropped for two reasons: a) it was the only categorical variable of the S.Inf factor that was not significant in the regression while at the same time returned the least value of standardized coefficient; and b) it showed relatively high correlation with 'extension services (Ext)' that had much higher standardized coefficient.

With these two adjustments, the model was amended to become:

$$\ln Y_k = \beta_0 + \sum_{i=1}^{3} \beta_{v_s}^{i} \ln\left(X_{v_s}^{i}\right)_k + \left[\sum_{i=1}^{5} \beta_{s_1}^{i} \ln\left(X_{s_1}^{i}\right)_k + \sum_{i=1}^{3} \beta_{s_2}^{i} \ln\left(X_{s_2}^{i}\right)_k + \beta_{s_3}^{1} X_{s_3}^{1} + \sum_{i=1}^{5} \beta_{e_d}^{i} \ln\left(X_{e_d}^{i}\right)_k\right] + \mu_k \quad \textbf{(6)}$$

In order to determine the influence of S.Inf factor on CS factor, robust linear regression and post-estimation analyses were undertaken systematically in three phases:

A) In the first phase, from equation (6), robust regression was used: (A.1) to assess the effect of CS on yield; (A.2) to assess the level of interaction between the categories of the four factors as follows: (A.2.1) The 'possession of email address (Eml)' and S.Inf categories were interacted with U.Inf categories in order to select the S.Inf categories that exhibited significant interaction with 'best management practice (BMP)' category. Since it is the U.Inf factor that informs the choice of a CS option, this selection enabled dropping of U.Inf factor in subsequent analysis; (A.2.2) All the FD categories were interacted with Eml and each of the S.Inf's categories in order to select the FD categories that exhibited significant interaction with S.Inf factor.

B) The second phase entailed post-estimation analysis where margins analyses and hierarchical regression were used to obtain projected mean yield (PMY), marginal effect (dydx) and change in coefficient of determination (ΔR2) values. To achieve this, a series of four regression analyses were undertaken involving the four factors sequentially as follows: (B.1) Regression analysis interacting one of CS category, one of S.Inf category and one (or none) of FD categories; (B.2) Margins analysis involving the selected CS and S.Inf categories to determine the projected mean yield (PMY). This included plotting of the resulting graph; next, (B.3) Marginal effect analysis to determine the values of the two PMY slopes (dydx) from graphs in analysis (B.2) above; lastly, (B.4) Hierarchical regression analysis (based on the model defined in analysis (B.1) above). Sequentially, the selected FD category was added to the rest of model in order to obtain the change in coefficient of determination (ΔR2). These set of 4 analyses were repeated to the exhaustion of all the categorical variables from all the factors. This resulted in 6 tableaus.

C) Finally in the third phase, the influence of S.Inf factor was computed from combination of the PMY, dydx, and ΔR2 values generated in the second phase of analysis. This study terms each of the computed values as resultant effect value (REV). The following rationale was applied in choosing the REVs as the measure of the influence of S.Inf: (1) the three values are quantitatively comparable within a single digit and decimal places; 2) they all vary in direct proportionality to their respective effects; (3) therefore, they are amenable to mathematical combination to generate resultant values (REVs in this case). The REVs give a combination effect that is similar to mapping points from three dimensions to a fourth dimension in a Cartesian coordinate system. To this extent, the operation of addition and subtraction was used to compute the REVs as follows: (C.1) the difference between corresponding pairs of PMY, dydx and ΔR2 values were obtained; (C.2) for each FD category the computed values in C.1 were summed up. This 'sum' (named 'REV [Sum]') is what constitutes the REV that gives the influence of a given S.Inf category on CS factor subject to the specified FD variable; (C.3) finally, the difference between a given 'REV [Sum]' and its corresponding 'REV [Sum]' where the FD variable was not specified was obtained. This result, termed as 'REV [No FD]' gives the influence of FD factor on S.Inf factor; (C.4) the computations up to step C.3 resulted in a tableau that was then systematically sorted first by S.Inf, then by CS, then by type of analysis, and finally by the 'REV [Sum]'; (C.5) a separate tableau was extracted as a portion of the tableau in step C.4, consisting of CS category with the highest coefficient of determination (R2 >0.46) value and corresponding to dydx analysis; (C.6) from the tableau in step C.5, two tables were generated. The first one to provide aggregated influence of each S.Inf category for all the FD categories while the other to give the aggregate influence each FD category for all the S.Inf categories; (C.7) finally, in order to examine the influence of Internet and telephone (whose marginal effects were not estimable), another tableau was extracted from the tableau in step C.4 using the same method as in step C.5 above.

RESULTS

From the descriptive statistics, the proportions of farming duration stood at: '<1' year - 6%; '1to5' years - 41%; '6to10' years - 28%; '11to15' years - 10%; and '>15' years - 14%. The proportions of usage of sources of information stood at: email - 11%; radio - 45%; TV - 18%; telephone - 3%; Internet - 6%; farmer group - 18%; and extension service - 62%. Further, more than 95% of the respondents did not measure nor record any data from the selected crop production and monitoring activities including crop spacing.

From the robust regression analysis, table 1 gives the effect of CS on yield. Though all the CS categories show significant (P=0) negative effect on yield, the 'NK' (not known) category shows the most negative effect and also the highest standardized coefficient (-0.77). In addition, all the S.Inf categories significantly interacted with the BMP U.Inf category (P<0.05). Consequently, all the S.Inf categories qualified to be included the second phase of analysis.

Table 1: Effect of Crop Spacing on Yield (n=356, at 95% CI)

Yield	Coef.	RSE	t	P>t	Std.Coef.
CS: [30x75]	-0.5398792	0.0993158	-5.44	0	-0.1235005
CS: [20x50]	0	(omitted)			0
CS: [Othr]	-0.3763704	0.0747694	-5.03	0	-0.0972493
CS: [NK]	-2.588038	0.1530511	-16.91	0	-0.7725244
_cons	4.040752	0.035647	113.35	0	.

Key: CS – crop spacing; CI – confidence interval; RSE – robust standard error; NK – not known

From the second phase of analysis, table 2 shows the S.Inf and FD categories whose interaction exhibited significant (P<0.05) effect on yield. The standardized coefficients of radio are the highest at +0.25 followed by email (+0.06) then telephone (+0.05 and +0.04). Internet, telephone and radio constitute information sources that are related with information communication technologies (ICT's). As such, among the ICT-related sources of information, Internet is the odd one with a negative standard coefficient of -0.11.

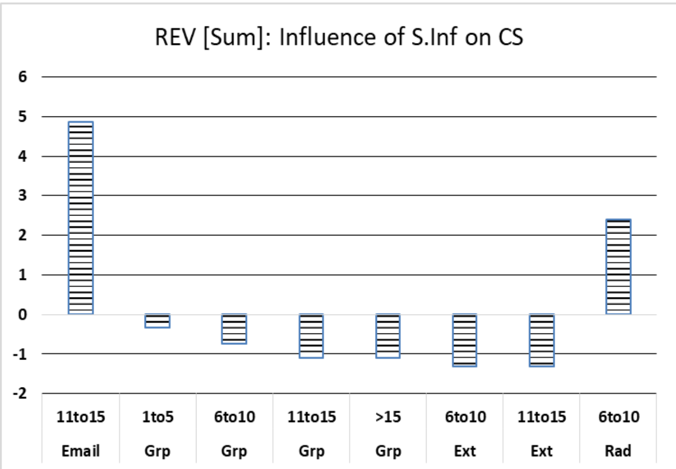
Though having negative effect, in absolute terms, extension services have the highest overall effect at 0.42 followed by farmer group at 0.31. Farmer group as source of information shows significant effect when interacted with all the FD categories while extension services is significant only when interacted with the >6 years FD categories. Conversely, save for possession of email address, the ICT-related sources of information show significant effect when interacted with the <10 years FD categories.

Table 2: Effect of Interaction of FD, S.Inf and Eml on Yield (n=356, at 95% CI)

S.Inf	FD	Coef.	Robust SE	t	P	Std.Coef.
Email	11to15	1.320894	0.600449	2.2	0.028	0.06033
Internet	1to5	-0.90656	0.349968	-2.59	0.01	-0.11478
Tel.	6to10	1.604814	0.409408	3.92	0	0.051903
	1to5	0.595422	0.402224	1.48	0.14	0.038351
Grp.	>15	-1.48120	0.622821	-2.38	0.018	-0.14955
	11to15	-1.81767	0.874528	-2.08	0.038	-0.15422
	6to10	-2.13417	0.598768	-3.56	0	-0.262
	1to5	-1.85892	0.412884	-4.5	0	-0.31073
Ext.	11to15	-2.72558	0.616587	-4.42	0	-0.41762
	6to10	-1.55795	0.602528	-2.59	0.01	-0.39011
Radio	6to10	1.236947	0.484483	2.55	0.011	0.248774

Key: S.Inf – source of information; FD – farming duration; Email – possession of email address; Grp – farmer group; Ext – extension services; Rad – radio;

From the third phase of data analysis, figure 1 represents the influence of sources of information on crop spacing when the farming duration factor is included (see 'REV [Sum]' in data analysis step (C.2).



Key:
REV – resultant effect value
S.Inf – source of information
CS – crop spacing
1to5 – 1 to 5 years farming duration (FD)
6to10 – 6 to 10 years FD
11to15 – 11 to 15 years FD
>15 – greater than 15 years FD
Email – possession of an email address
Grp – farmer group
Ext – extension services
Rad - radio

Figure 1: Influence of S.Inf w.r.t FD on Effect of CS on Yield (n=356, at 95% CI)

The highest influence, at +4.9, is from possession of email address when interacted with the '11to15' FD category. This is closely followed by influence of +2.4 from radio when interacted with the '6to10' FD category. In a graduated manner, are the influences at -1.1, -0.7, and -0.3 from farmer group when interacted with the '11to15', '6to10' and '1to5' FD categories respectively. The lowest influence at -1.3 is from extension services.

Two bar graphs were generated, from the two tableaus generated in step C.6 of data analysis, to represent the aggregate influence of S.Inf factor and FD factor as shown in figures 2 and 3. In figure 3, only the '11 to 15' and '6to10' FD categories have positive influence at +2.4 and +0.3 respectively. In contrast, the '>15' and '1to5' FD categories showed negative influence at -1.1 and -0.3 respectively.

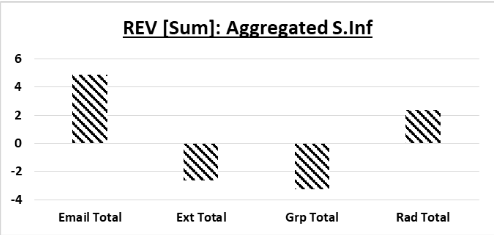


Figure 2: Aggregated Influence of S.inf ∀ FD on Effect of CS on Yield

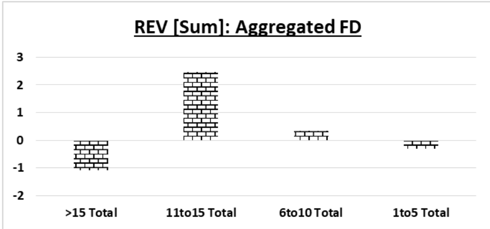
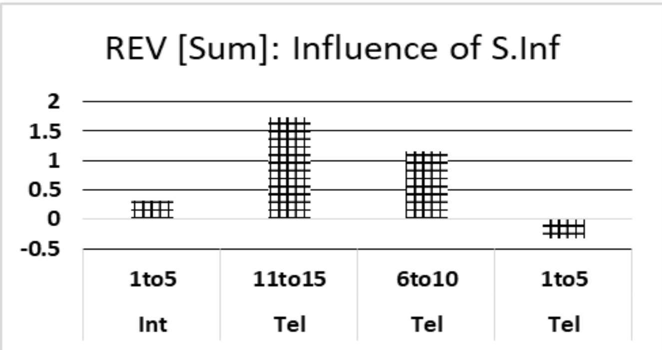


Figure 3: Aggregated Influence of FD ∀ S.Inf on Effect of CS on Yield

Key:
REV – resultant effect value
S.Inf – source of information
FD – farming duration
1to5 – 1 to 5 years FD
6to10 – 6 to 10 years FD
11to15 – 11 to 15 years FD
Grp – farmer group
Ext – extension services
Rad - radio

In order to obtain a more complete depiction of the influence of S.Inf factor, Internet and telephone categories were analyzed, notwithstanding that some of their post estimation results were not measurable. Two bar graphs were generated from the tableau obtained in step C.7 of data analysis. The first (see figure 4) represents the 'REV [sum]' (see data analysis step C.2).



Key:
REV – resultant effect value
S.Inf – source of information
FD – farming duration
1to5 – 1 to 5 years FD
6to10 – 6 to 10 years FD
11to15 – 11 to 15 years FD
Int – Internet
Tel – telephone

Figure 4: Influence of S.Inf w.r.t FD on Effect of Crop Spacing on Yield

From figure 4, Internet shows influence of +0.3 when interacted with the '1to5' FD category. Telephone's influence is graduated in tandem with decreasing farming duration at +1.7, +1.2, and -0.3 when interacted with the '11to15', '6to10', and '1to5' FD categories respectively.

DISCUSSION

From table 1, 'NK' CS category has the highest standardized coefficient at 0.77. This implies that, irrespective of the source of information, the lack of knowledge of the recommended potato crop spacing is widespread. Consequently, this implies existence of as varied permutations of crop spacing specifications as influenced by both S.Inf and FD factors. This vividly depicts the extent of uncertainty in the prevailing production plans and clearly demonstrates sub-optimality of Malmgren's (1961) "expectational equilibrium". This prevalence of 'NK' category is consistent with poor knowledge management as observed by Amara et al., (1999) and Obare et al., (2010). It is also consistent with low level of precision in implementation of TIMPs as observed by Wang'ombe & Djik (2013). The ensuing negative effect on productivity translates to 13.06t/Ha that is consistent with Kenya's 9-15 t/Ha according to (FAO, 2020). This realized yield gives an initial indication of the contribution to the prevailing persistent low productivity by IM and resultant crop management practices.

From the standardized coefficients in table 2, extension services show the highest absolute standardized coefficient of 0.42. This result is consistent with the finding by Nenkari, (2010) that extension services is traditionally regarded as one of the foremost sources of information for BMP. However, its negative effect is consistent with the finding by Anderson (2007) on the deteriorating efficacy of extension services. In contrast, radio, which is essentially extension services vide electronic broadcast media (ICT-related), shows the highest positive effect at +0.25. Raabe (2008), corroborates this shift towards mass media as one of the most effective sources of information.

Table 2 further demonstrates a generational shift towards ICT-related sources of information. While extension services is significant when interacted with the >6 years FD categories, the ICT-related sources show significant effect when interacted with the <10 years FD categories. However, possession of email address is an exception to this trend in two ways. Firstly, it is significant when interacted with the '11to15' FD category. Secondly, it has a positive standardized coefficient of 0.06 contrary to Internet's -0.11. This contradiction prompted separate analysis of additional socio-economic data from the survey. The result of this analysis showed that the '11to15' FD category had the least correlation with both the household size (0.01, P=0.85), and the estimated school fees liability (0.03, P=0.61). Further, this category showed the highest correlation with access to credit from savings groups (0.23, P=0) as well as ownership of cattle (0.1, P=0.07). Cattle ownership implies possible membership in formal dairy cooperatives. Affiliation with such formal cooperatives obligates possession of email address for access to online Government services, particularly tax-related. This finding therefore demonstrates that the '11to15' FD category is not only likely obligated to access Internet services, but also enjoys higher marginal propensity to consume (MPC) from extra finances from regular milk sales and easily accessible low-cost credit from farmer-groups.

The MPC factor corroborates the important aspect of cost of information discover (CID) as postulated by Malmgren (1961). The higher MPC by the '11to15' FD category caters for the recurrent 'airtime/ Internet bundle' financial cost of Internet usage. On the other hand, Internet per see shows significant interaction with the '1to5' FD category that is not shown to enjoy high MPC. This trend corroborates the assumption that the graduation of FD categories is concomitant with the age of the farmers. As such, the younger farmers possess higher Internet usage proficiency having benefited from early exposure to the recently ubiquitous advanced telephony technologies such as smart phones. This implies that proficiency CID complements financial CID as expected. However, the negative effect (-0.11) of Internet with the '1to5' FD category demonstrates that proficiency CID is less limiting than the financial CID but is not sufficient for effective usage. These CID arguments apply, similarly, in the case of telephone where the '1to5' FD category has lower standardized coefficient of 0.04 compared to 0.05 by the '6to10' FD category. This shows that, having lower MPC, the younger farmers are not able to make as effective use of telephone as their older counterparts. Finally, the CID aspect is evident in the case of farmer group whose interaction is significant with all the FD categories. This universality of access implies near non-existent CID. Further, the graduated standardized coefficients at -0.31 and -0.26, for the '1to5 and '6to10' FD categories respectively implies heavier usage of farmer group by the '1to5' FD category. This corroborates the earlier conclusion that FD categories are graduated concomitant with the age of farmers and their respective MPC levels.

Ensuing from the post-estimation analyses, the study utilized the REVs to isolate the explicit influence of the S.Inf factor. The pattern of the REVs in figure 1 are similar in sign and trend with the standardized coefficient values in Table 2 except for possession of email address and radio. For these two ICT-related sources of information, the magnitude of REV is much higher, at +4.9 and +2.4, compared with their standardized coefficients, at 0.06 and 0.25, respectively. In addition, this REV outcome contradicts the proportionality of usage of the two S.Inf categories that are given as 11% and 45% respectively. This contradiction is however consistent with the assertion by Aithiguru et al., (2009) and Mittal et al., (2014) that "the quality of information, its timeliness, and trustworthiness are the three important features that enable farmers to use mobile-enabled sources more effectively". As opposed to radio, TIMPs information in the Internet are hosted by reputable entities and are readily available on-demand. This superiority of Internet is corroborated further in figure 4 where the influence of Internet S.Inf category is positive (+0.3) and consistent with the influence of possession of email address (+4.9). The lower influence of radio compared to that of Internet (as inferenced from possession of email address) is further consistent with the finding by Ferroni & Zhou (2012) that, where private entities are involved in extension services (in the field or popularly through radio programs) it is mostly to provide extension as part of sales or promotion schemes to ensure proper use of their inputs. As such, the information provided through radio may not focus on precision of implementation of TIMPS such as crop spacing. In contrast with the positive influence of the ICT-related sources of information, the REVs in figure 1 shows that the influence of both farmer group and extension services are negative and graduated in tandem with their standardized coefficients provided in table 2. This negative influence of the extension services is consistent with the finding that Government extension services are eclipsed by private players, mainly input dealers, who provide extension services with focus on sales and appropriate usage of inputs (Ferroni & Zhou, 2012), (Raabe, 2008), and (Anderson, 2007).

Figure 2 provides the aggregate influence of each category of source of information for all the farming duration categories. Figure 3 provides the aggregate influence of each farming duration category for all the sources of information categories. The ICT-related sources of information show positive aggregate influence in tandem with the '11to15' followed by the '6to10' FD categories. Conversely, the traditional sources of information show negative aggregate influence in sync with the '1to5' and '>15' FD categories. This corroborates the superiority of ICT-related sources over the traditional sources of information.

CONCLUSION AND RECOMMENDATION

This study establishes that in the location of study, traditional mode of extension services followed by farmer group are the most prevalent sources of information. Unfortunately, both sources have negative influence on the effect of crop spacing on yield. In addition, though less prevalent, the ICT-related sources of information have positive influence with Internet being better than radio. Unfortunately, also, Internet is shown to exclude both the shortest and the longest farming duration categories due to financial and proficiency CID respectively. Similarly, broadcast media is found to focus on proper use of inputs as part of product promotion by private suppliers. In general, irrespective of the information source, lack of knowledge of the recommended crop spacing is extensive as demonstrated by the predominant choice of 'not known' crop spacing category. This indicates that all the sources of information do not promote the element of precision of crop management. As such, precision is neither appreciated nor prioritized among the SPF community.

This outcome demonstrates that lack of precision in SPF is associated with uncertainty of production information due to CID and deteriorating efficacy of traditional forms of information dissemination. One result of this uncertainty in information and crop management practices is sub-optimal production plans that culminate in and propagate the persistent low productivity. This study therefore corroborates the propositions from other studies on the need for innovative mechanisms for TIMPs information management that enable objective decision making and foster precision in their implementation. One such proposed mechanism is use of field-specific DSS. This study, in addition, proposes that the DSS can be implemented as part of PA as a system integrated into the traditional potato production process.

Given the lack of studies thereof, this study recommends further research to establish the impact of DSS on productivity among the smallholder potato farmers in the North-rift highlands of Kenya. It is however informative to note that such a study is ongoing and is due to be completed by December 2022.

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Conflict of Interest
The author declares no conflict of interest.

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