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Full Length Research Paper

Dairy farmer households' farm gate milk price heterogeneity in Kericho County, Kenya

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This study aimed at identifying factors affecting farm gate milk price heterogeneity in dairy farmer households in Kericho County, Kenya. Multistage cluster sampling technique was used to collect data from 432 dairy farmer households. To estimate survey data, multivariate probit and selectivity biased mixed-effects linear regression models were used. Results showed that increased daily milk output sold and number of commercial milk buyers resulted in increased probability of farm gate milk price variability by 3.8 and 12%, respectively. However, number of milking cows and trust levels on commercial milk buyer by seller decreased farm gate milk price heterogeneity by 89 and 87%, respectively. While selling through commercial, milk buyers had significant positive effect on farm gate milk price, majority of dairy farmer households were hesitant to engage with them since milk buyers valued supply security which came from trusted relationships and contracts. Therefore, critical strategies to improve farm gate milk prices are needed. These include strengthening of dairy farmer groups and partnership development, bolstering milk cooperative societies and increased financial investments in livestock milk markets by national and county governments.

Key words: Farm gate milk price, price heterogeneity, mixed-effects linear regression, dairy farmer households, Kericho County, Kenya.

INTRODUCTION

Numerous studies have shown that agricultural markets in developing countries, including sub-Saharan Africa (SSA), are undergoing rapid changes in response to strong economic growth, improved infrastructure and communication systems, and growing demand among consumers for higher quality products. Associated with and facilitating these changes are a range of new interventions and investments, from creative ways to finance value chains, to Information Communication Technology (ICT) solutions for the quick and reliable delivery of market information for farmers, to new organizational approaches for linking small farmers to markets (ILRI, 2011). According to Beneberu et al. (2011), livestock milk marketing is a favorite sector, where African governments choose to intervene in a variety of ways. These interventions range from outright

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fixing of wholesale and retail milk prices to monopolizing the export market, yet in many instances policy decisions on livestock milk marketing are taken in the absence of vital information on how they affect small-scale livestock producers, traders and consumers. Very often price fixing at unrealistic levels leads to open black markets, where the real prices substantially differ from those officially listed (Beneberu et al., 2011).

According to FAO (2011), global livestock milk markets offers processors and suppliers increased income and direct cost savings, but they are also posing the threat of market exclusion. A considerable potential to enhance milk market access and marketing success may be available through the promotion of farmer groups, community-based organizations and cooperatives (FAO, 2011). Output prices received by farmers significantly determine their welfare especially in rural areas where there is weak non-farm income which limits diversification of agricultural production amongst producers. While there are debates about the actual and potential impacts of having a wide array of commercial milk buyers on broader welfare of the rural poor; case study evidence suggests that farmers are worst placed when faced with a privately owned or government-controlled monopsony (Gorton and White, 2007; Sadler, 2006). Farmers' welfare depends mostly on the price received for their output in environments of minimal agricultural policy support, the absence of social safety nets, and a weak non-farm rural economy which limits agricultural diversification (Sauer et al., 2012). These features characterize much of Kericho County, where rural poverty is widespread.

In the study county, daily milk price received by dairy farmer households for their milk output had been of considerable concern. Evidence has shown that farm gate milk prices have often been significantly variable and vary considerably between farmer household milk producers. Dairy farmers have been unaware of milk prices received by other farmers due to the weak physical and commercial infrastructure. According to Liefert and Liefert (2007), poor physical and commercial/institutional infrastructure raises transport and transaction costs.

Dairy cooperative societies within Kericho County, which used to be an integral part of the formal milk collection and marketing, have been relegated to buyers of last resort due to their low milk purchase prices. These cooperative societies have been marketing big proportion of their milk directly to processors and urban markets within the county. However, farm gate raw milk prices from the milk buyers have been fluctuating periodically to levels too low to cover farmers' costs of production (KDB, 2015). According to Business Daily (2014), New Kenya Cooperative Creameries (KCC) followed Brookside dairy processor by lowering farm gate milk price and in delaying payment for unsold milk stocks to farmers. New KCC bought raw milk at Kenya Shillings (KES) 32 per litre from KES 40 in March, 2014, while Brookside lowered its farm gate milk price to KES 30 from KES 35 and 40 in March and February, 2014, respectively. By end of March 2014, New KCC had lowered its farm gate milk price payments by 20% while Brookside Dairies had lowered by 14.3 and 25% in March and February, 2014, respectively.

Jari (2009) argues that despite the fact that smallholder farmers face difficulties in marketing, they continue to produce and survive in the face of unfavourable conditions some of which can be solved through use of trusted marketing channels. Farmers maximize return on investments through value addition, complimenting own produce from other sources as well as offering diversified products from the same material inputs. When selling their products, such farmers will use marketing channels that enable their produce to reach the market at least cost per unit of output. By pooling skilled manpower, dairy farmers who are chain actors are able to minimize on transaction costs, access market information and adhere to government regulations more easily.

Dairy farmers are able to take collective action on securing new markets, bargaining for better prices for milk and milk products and use of the most effective marketing channel. Such actions are taken against a background of strong associations by farmers who are trained and have a strong entrepreneurial orientation. However, Sauer et al. (2012) argues that farmers' welfare depends mostly on the price received for their output in environments of minimal agricultural policy support, the absence of social safety nets, and a weak non-farm rural economy which limits agricultural diversification.

Therefore, the motivation of this study was to bridge the literature gap using multivariate probit and selectivity biased mixed-effects linear regression models to explain determinants of price heterogeneity between dairy farmer households and within the county. By considering the causal relationship between participation in selling milk to commercial milk buyers and dairy farmer household welfare, this study anticipated that the findings would address the counterfactual queries that were important in forecasting the impacts of policy changes and that for alleviating dairy farmer household income security in Kericho County, Kenya.

MATERIALS AND METHODS

Sampling procedure

The target population was restricted to 94,427 smallholder livestock milk producers and marketers, divided proportionately amongst the six sub-counties of Kericho County, Kenya. Multistage cluster sampling procedure was then used to get the sample size of interest. The county was clustered into six sub-counties that formed sample sites for the study. To achieve representative sample size, the six sub-counties formed the first-stage cluster that had the target population. These clusters were selected based on the fact that small scale dairy farming was dominant and practiced throughout the six sub-counties. It also reflected significant differences in structure of the dairy milk marketing business in the county. Within the six sub-counties, second-stage cluster sample of wards and villages with high concentration of small scale dairy farmers was then selected. The sampled milk producing n^{th} smallholder dairy farmer household was determined by the proportionate size sampling methodology (Anderson et al., 2007) as shown in Equation 1.

$$N_0 = \frac{Z^2 pq}{e^2} \quad (1)$$

where N_0 is the sample size, Z is the standard normal value of 1.96 significant at 5% confidence level, *e* is the margin of error, *p* is the estimated population proportion of dairy farmers with characteristics of interest, q = 1-p, Z = 1.96, and e = degree of precision.

Sample units were calculated proportionately based on the number of dairy farmer households in each sub county and as a proportion of the total dairy farmers in the county against the desired sample size of 504. Based on the aforementioned criteria, the random sample of dairy farmer households selling raw milk to different milk marketing channels was set for the whole county consisting of 75 farmers from Kipkelion East, 63 from Kipkelion West, 91 from Kericho West, 44 from Kericho East, 81 from Soin/Sigowet and 150 from Bureti. After data cleaning, 432 observations remained for analysis.

Data

This study used both primary and secondary data. The data was collected through cross-sectional sample design for dairy farmer households. Seasonal observation involved observing the natural behaviour of the dairy farmer households in order to describe the existing situation and to obtain information that were relevant to the goals of the study. Secondary data was obtained from existing published literature desktop literature and internet. Farm records from a sampled of few farmer households were also used to supplement secondary data sources.

Data types

The data types that were used in this study encompassed representative sample of dairy farmer households representing the various household categories, types of commercial and non-commercial milk marketing channels and changing structure of dairy sector. To analyze the responses of milk producers, the study categorized the choice of milk marketing channels into a binary outcome, whether the dairy farmer household sold milk at farm gate to commercial milk marketing channels (Y_1) and if farmer household chose to sell also to final consumers (non-commercial channel) or otherwise (Y_0). Data collected included dairy farmers' socio-economic characteristics, actual milk production, milk market competitiveness and other related obligations with the milk buyers. Farm production data comprised of the size of land under dairy production, average volume of milk produced per day, amount of livestock inputs and farm gate milk prices.

Respondents also provided information regarding market competitiveness and estimated total number of potential commercial buyers for their milk. This would capture the degree of switching power of the dairy farmer household from one commercial buyer to the other. The study also included data on whether the farmer sold per day total milk output on contract signing or on spot cash sale. To capture the trustworthiness of commercial milk buyers, a measure of trust on the commercial milk buyer by the dairy milk farmer household was included. This characteristic was analyzed by a proxy that identified the perception that the dairy milk farmer had in relation to their trust in the commercial milk buyer.

Regarding milk marketing characteristic, a dummy variable was introduced to capture whether the dairy farmer household sold via milk cooling/chilling plants (cooperative society), milk sheds or through milk bars or not. Time series data on farm gate milk prices received by the farmer household over a period of three years (2013, 2014 and 2015) was also collected from the farmers. This entailed use of pair wise comparison of the six sub county mean milk prices for the three years using Tukey's HSD (honest significant difference) test.

Data analysis and diagnostics

Econometric analysis of data consisted of two stages. Multivariate probit model was used in the first stage to estimate factors which determined milk marketing channel choice decision equation, specifically whether farmers sold raw milk only to a commercial milk buyer or sold also to a final consumer. Secondly, mixed effects linear regression model was used in the analysis of determinants of farm gate milk price heterogeneity in the county. The two empirical models for data analysis were linked by the inverse Mill's ratio (*MR*). The study assumed that it was likely that the characteristics of small scale dairy farmer who sold milk only to a commercial buyer differed from those who sold also to final consumers. However, selection effect or bias correction factor exists in cross sectional data since farmers themselves decide whether or not to sell to a particular marketing channel. Consequently, those who sold and those not could differ systematically, leading to non-random selection bias. Therefore, diagnostic tests were conducted from the regression results of STATA output. To check on multicollinearity, the study used variance inflation factor (VIF) and contingency coefficient (CC) among discrete and continuous variables, respectively. All assumptions were tested and corrected accordingly.

Theoretical framework

According to rational choice theory, individual households' rank mutually exclusive alternative decisions in order of utility and will choose the alternative with maximum expected utility given their socio-economic and demographic characteristics and relevant resource constraints. Hence, in this study, the producer's milk marketing channel choice that fetched better milk price was conceptualized using a random utility model (RUM). It was assumed that economic agents, including smallholder dairy farmers, use certain livestock milk marketing systems only when the perceived utility or net benefit from using such a method is significantly greater than is the case without it. Again, smallholder dairy farmers were assumed to be rational and they want to derive the highest utility from the choices they make; either to market their produce independently or under a certain milk marketing channel depending on the returns. They made their choices with respect to random utility theory. The choice decision maker was guided by unobservable, observable and random characteristics while making a decision. Although utility was not directly observed, the actions of economic agents were observed through the choices they made.

The study formulated milk marketing channel selection/choice decision as a two-alternative choice (selling to commercial milk buyer(s) = 1 and selling to final milk consumer(s) = 0).

Let a decision maker (dairy farmer with raw milk for sale) choose from a set of mutually exclusive alternatives, j = 1, 2,…, J. The decision maker obtains a certain level of utility U_{ij} from each alternative. The discrete choice model is based on the principle that the decision-maker chooses the outcome that maximizes the utility. The producer makes a marginal benefit-marginal cost calculation based on the utility achieved by selling to a market channel or to another. His/Her utility is not observed, but some attributes of the alternatives as faced by the decision-maker are observed. Hence, the utility is decomposed into deterministic (V_{ij}) and random (ε_{ij}) part:

$$U_{ij} = V_{ij} + \varepsilon_{ij}; \forall_{ij} \in \mathrm{N} \quad (2)$$

Since ε_{ij} is not observed, the decision-makers' choice cannot be predicted exactly. Instead, the probability of any particular outcome is derived. The utilities or the difference between benefit and cost cannot be observed directly, but the choice made by the producer reveals which one provides the greater utility (Greene, 2003).

A producer selects market channel j=1 if;

$$U_{ik} > U_{ij} \forall_{j} \neq k \quad (3)$$

where U_{ik} denotes a random utility associated with the market channel j = k, and V_{ij} is an index function denoting the producer' average utility associated with this alternative. The second term ε_{ij} denotes a random error which is specific to a producer's utility preference (McFadden, 2000). Now, suppose that Y_i and Y_j represent a household's utility for two milk marketing choices, which are denoted by U_i and U_j, respectively. The linear random utility model, the milk marketing channel choice is modeled as in equation 4.

$$U_{ij} = \beta_j X_{ij} + \varepsilon_{ij} \quad (4)$$

where U_{ij} is a vector of the milk marketing channel choices (j = 1 commercial milk buyers; and 0 for final milk consumers) of i^{th} dairy farmer, β_j is a vector of channel-specific parameters. ε_{ij} is the error term assumed to have a distribution with mean 0 and variance 1 and identically distributed (Greene, 2003). X_{ij} is the vector of explanatory variables that determined and or influenced the perceived desirability of the choice of the milk marketing channel. Therefore, for the case of choice of a livestock milk marketing channel, if a dairy farmer household decides to use option *j* marketing channel, it follows that the perceived utility or benefit from option *j* marketing channel is greater than the utility from other options (say *k*) marketing channel depicted as follows:

$$U_{ij}(\beta_j^1 X_i + \varepsilon_j) > (U_{ik}(\beta_k^1 X_i + \varepsilon_k), \quad k \neq j \quad (5)$$

The probability that a dairy farmer will choose milk marketing channel *j* among the set of livestock milk marketing channels to market his milk instead of the *k* marketing channel could then be defined as:

$$P(Y = 1 \mid X) = P(U_{ij} > U_{ij}) \quad (6)$$

Therefore,

$$P(\beta_j^1 X_i + \varepsilon_j - \beta_k^1 X_i - \varepsilon_k > 0 \mid X) \quad (7)$$

Hence $P(\beta_j^1 X_i - \beta_k^1 X_i + \varepsilon_j - \varepsilon_k > 0 \mid X)$

$$P(X^* X_i + \varepsilon^* > 0 \mid X = F(\beta^* X_i) \quad (8)$$

where *P* is a probability function, U_{ij}, U_{ik}, and X_i are as defined earlier, $\varepsilon^* = \varepsilon_j - \varepsilon_k$ is a random disturbance term, $\beta_j^* = (\beta_j^1 - \beta_k^1)$ is a vector of unknown parameters that can be interpreted as a net influence of the vector of independent variables influencing the choice of a milk market, and $F(B^* X_i)$ is a cumulative distribution function of the error terms (ε^*) evaluated at $B^* X_i$. The exact distribution of *F* depends on the distribution of the random disturbance term, ε^*. Depending on the assumed distribution that the random disturbance term follows, several qualitative choice models can be estimated (Greene, 2003).

The choice of a milk marketing channel that offered better milk price was fundamental and important decision for the dairy farmer households. Consistent with the theoretical model, the study assumed that dairy farmer households practiced dairy farming for good milk price and income maximization, to smooth household income through market guarantee and market access and production volume utility respectively despite liquidity constraints. Others practiced dairy farming for prestige. However, liquidity preference played a major role in dairy farmer households' decision for particular milk marketing channel.

Analytical framework

Multivariate probit and mixed effects linear regression models were used in the analysis of the determinants of farm gate milk price heterogeneity in small holder dairy farmer household in Kericho County, Kenya. However, the two empirical models for data analysis were linked by the inverse Mill's ratio (*MR*) inferred in Equation 14. The study assumed that it was likely that the characteristics of small scale dairy farmer household that sold milk only to a commercial buyer differed from those that sold also to final consumers. However, selection effect or bias correction factor exists in cross sectional data since farmers themselves decide whether or not to sell to a particular marketing channel. Consequently, those who sell and those not could differ systematically, leading to non-random selection bias. Estimation and inference problems in econometric models would arise if incorrect non endogeneity assumption about the structure of the decision making process is made. The selection model of Heckman (1979) describes an estimation problem resulting from incomplete data leading to simultaneity problem. Data in the milk marketing channel choice analysis assumed that milk prices would only be observed for the subsample of dairy farmer households who sold milk to commercial buyers. Milk selling depended on covariates that were assumed to affect milk price, or the price that was needed to be offered to induce a dairy farmer to enter the milk market. According to Heckman (1979), econometric model postulates that if a wage offer exceeds the reservation wage, then the wage will be observed for that individual, which was also applied to the milk price in this study. The selection problem was that milk price was only observed for a dairy farmer household that sold milk to a commercial milk buyer and milk price was unobserved or latent for those that sold to final consumers. Therefore, to account for selection bias, two equations were envisaged (adopted from Heckman 1979):

$Y_0 = X\beta + u_1$, (price offered) and $Y_\tau = X\beta + u_2$, (reservation price) (9)

It follows then that, $Y = Y_0$ if $Y_0 \geq Y_\tau$ and *Y* is missing or 0 otherwise. Selectivity bias refers to the fact that if this study was to estimate the milk price function based on observations for which there was data, then the estimates of the effects of variables that determined milk price rates would be inconsistent and biased. Therefore, this study viewed the price equation as the substantive equation of interest and specified as follows:

$$Y = X\beta + u_1, \tag{10}$$

along with a milk selling (participation) equation,

$$P^* = Z\gamma + u_2, \tag{11}$$

in which a dairy farmer household sells milk if $P^* \geq 0,$ and

$$\Pr(P = 1|Z) = \Phi(Z\gamma) \tag{12}$$

It can be shown that,

$$E(u_1 \mid P = 1) = E(u_1 \mid u_2 > -Z\gamma) = E(u_1 \mid u_2 < Z\gamma) = \sigma_{12}\left[\frac{\phi(Z\gamma)}{\Phi(Z\gamma)}\right] \tag{13}$$

By symmetry of normal distribution, the study had:

$$\frac{\phi(\text{-z})}{1-\Phi(-z)} = \frac{\phi(\text{z})}{\Phi(z)}$$

and

$$\frac{\phi(\text{-z})}{\Phi(-z)} = \frac{\phi(\text{z})}{1-\Phi(z)} \tag{14}$$

The ratio $\frac{\phi(\text{z})}{\Phi(z)}$ is the inverse Mills ratio (or non-selection hazard rate) and, $\frac{\phi(\text{z})}{1-\Phi(z)} = \frac{\phi(\text{z})}{\Phi(-z)}$ is the selection hazard rate. Therefore, from the modeling stand point for this study hypothesis, multi-level modeling approach referred to as mixed-effects or hierarchical model adopted from Bryk and Raudenbush (2002) was used to estimate the determinants of variations in farm gate milk prices for those smallholder farmers who sold milk to commercial milk buyers only in the county as shown in Equation 15.

$P^* = Z\gamma + u_2,\ P = 1,$ if $P^* \geq 0,$ 0 otherwise

$Y^* = X\beta + u_1,\ Y^* = Y$ if $P = 1$ (15)

where P is a probit model; Y^* is a latent continuous dependent variable. In this study, milk prices were treated as continuous. The study also assumed that u_1 and u_2 were distributed as multivariate normal, with means zero, covariances $\sigma^2_{u_1}, \sigma^2_{u2}$, and $\sigma^3_{u_{12}}$. The inverse Mills ratio $\hat{\lambda} = \phi(Z\hat{\gamma}) / \Phi(Z\hat{\gamma})$ that was generated in objective one data was then included as a regressor in the mixed effects linear regression analyses model.

Estimation of the model

Mixed-effects linear regression or hierarchical model was used in this study to investigate the determinants of variations in farm gate milk prices for those smallholder farmers who sold to commercial buyers only in the county. The reason was because some of the covariates were grouped according to one or more characteristics. The mixed model was characterized as containing both fixed and random effects. The fixed effects were analogous to standard regression coefficients and were estimated directly. The random effects were not directly estimated but were summarized according to their estimated variances and covariances. According to Sauer et al. (2012) random effects may take the form of either random intercepts or random coefficients, and the grouping structure of the data may consist of multiple levels of nested groups, that is, the error distribution of the linear mixed model is assumed to be Gaussian.

In the study, the dependent variable was farm gate raw milk price in Kenya shillings (KES) per liter received by the dairy farmer household. Milk price data covered three years, with respondents providing average milk price received in the year 2013, 2014, and 2015, respectively. The Laird and Ware (1982) form of the milk price model (Equation 16) was adopted for this study:

$$P_{im} = \alpha + \varepsilon p_{imt-1} + \beta_1 X_{1im} + \beta_2 X_{2ijm} + \beta_3 X_{3ikm} + \beta_4 X_{4ikm} + \beta_5 X_{5ikm} + \beta_6 X_{6ikm} + \beta_7 X_{7ikm} + \beta_8 X_{8ikm}\beta_9 X_{9ikm} + \beta_{10} X_{10ikm} + \beta_{11}\lambda_{lm} + \sum_n b_n Z_{\ln m} + u_{lm} \tag{16}$$

$$b_n \sim \text{iid N}(0, \gamma b^2), \text{cov}(b_n, b_{n-1}) = \gamma_{n,n-1}, u \sim \text{iid N}(0, \sigma^2 \lambda_{im}), \text{cov}(u_{im} - u_{i-1}, m) = \sigma^2 \lambda_{imi-1}$$

.

The model was estimated by maximum restricted or residual likelihood (REML) (Harville, 1977). Where P_{im} is the price per liter of milk for the farmer i^{th} observation in the m^{th} sub-county; ε, υ, μ, ρ, τ, and ϕ are the fixed-effect coefficients which are identical for all the sub-counties m; P_{imt-1}, β_{1im}, β_{2im}, β_{3im}, and β_{4im} are the fixed-effect coefficients which were identical for all the six sub-counties (*m)*; P_{imt-1}, X_{1im}, X_{2im}, X_{3im}, and X_{4im} are the fixed-effect regressors for observation of farmer i in sub-county m (where P_{t-1} is the milk price in 2015; X_1 is the number of milking cows; and X_2 refers to distance to the nearest milk market, X_3 refers to the number of farm gate commercial milk buyers; X_4, X_5, X_6, X_7, X_8 and X_9 are total milk output sold via New KCC, Brookside Ltd, milk traders, self-help groups, home for consumption and milk output sold via milk cooling/chilling plants respectively. X_{10} is a vector of trust-related variable (trust in seller on buyer, a cross effect between trust and percentage of milk output sold to commercial milk buyer); and b_n are the random-effect coefficients for sub-county m, assumed to be multivariate and normally distributed and varying by sub-county; b_n are designed as random variables and are hence similar to the errors u; z_n are the random-effect regressors; γb^2 and $\gamma_{n,n-1}$ are variances and covariances among the random effects assumed to be constant across groups; u_{im} is the error for observation of farmer i in sub-county m assumed to be multivariately normally distributed also assumed to be Gaussian; $\sigma^2\lambda_{imi-1}$ are the covariances between errors in group m ($\lambda_{imi} = \sigma^2$, $\lambda_{imi-1} = 0$) (observations were sampled independently within the six sub-counties and were assumed to have constant error variance)). Fixed effects were assumed to be similar to standard regression coefficients and were estimated directly. However, the random effects were not directly estimated but were summarized according to their estimated variances and covariances. Random effects took the forms of either random intercepts or random coefficients, and the grouping structure of the data consisted of multiple levels of nested groups related to the six sub counties and trust levels. X_{11} is the Inverse Mills ratio (λ) obtained from the first stage regression controlling for potential selection bias. The use of this ratio was motivated by the property of the truncated normal distribution (Heckman, 1979).

RESULTS AND DISCUSSION

Characteristics of farmer households

As shown in Table 1 of results, majority of dairy farmer households owned two or one milking cows with the highest being 50 milking cows. The median herd size was 3 milking cows, while 160 of the sampled dairy farmer households owned two milking cows. From the results, 55% of dairy farmer households sold milk to commercial buyer(s), 40% sold to final consumers while 4% sold to both commercial buyer(s) and final consumers. However, some farmers sold milk in more than one market outlet depending on unit price offered, volume of milk produced, and urgency of the need for cash.

Table 2 presents farm gate milk price summary statistics for those dairy farmer households that sold to commercial milk buyers and final consumers. In 2013, 2014 and 2015, the actual average farm gate milk price received by all the farmers selling exclusively to commercial buyers in the county was Kenyan Shillings (KES) 29.91, 32.71 and 35.51 per liter per day, respectively. For the final consumers, the average farm gate milk price for the three years was KES 33.03, 37.31 and 41.65, respectively.

Results in Table 3 show the total number of potential commercial buyers of raw milk at farm gate for the surveyed farmers. Five commercial milk buyers existed in the study area, a clear indication of milk market competitiveness in the county. This also captured the degree of switching power that dairy farmer households had in marketing their raw milk and the degree to which markets were characterized in the county. The results as presented showed the mean milk price offered by the various commercial buyers on farm's milk output sold via milk marketing channels. Milk traders/vendors purchased raw milk at an average farm gate price of KES 36.80 per liter per day from 181 of farmers selling only to commercial buyers in the county. Milk traders/vendors offered a mean minimal price of KES 25 and a maximum price of KES 60 per liter of milk per day. Milk cooling/chilling plants (milk cooperative societies) and milk buying self-help groups bought milk from only 61 (14%) and 8 (2%) of the surveyed dairy farmer households at an average daily farm gate price of KES 33.34 and 37.5 per liter, respectively.

Diagnostic tests

Preliminary results for the diagnostic tests revealed that potential multicollinearity among explanatory variables was found not to have any potential influence on estimates from the model. The highest pair-wise correlation was 0.4, whereas multicollinearity is a serious problem if pair-wise correlation among regressors is in excess of 0.5 (Gujarati, 2004). An analysis of variance inflation factor (VIF) did not show any problem since none of the VIF of a variable exceeded 8 (Greene, 2003). The tests of the fixed effects as presented in Table 4 also provided the *F*-tests for each of the fixed effects that were specified in the study model. The random effects were not directly estimated but were summarized according to their estimated variances and covariances, that is, represented by random effect and residual covariance. Since the *p*- value of the *F*-test for overall significance test was less than the significance level, the null-hypothesis was rejected and conclusion was made that the model used in the study provided a better fit than the intercept-only model.

Heterogeneity in farm gate milk price coefficients

Table 5 presents the results of the mixed-effects linear regression model for the determinants of farm gate milk price in Kericho County obtained through Equation 16. The results also present a summary of the parameters that were used to specify the random effects and residual covariance matrices. Since no repeated effects were specified in the model, the error terms were independent with variance approximately 51.48. The random effects had the scaled identity variance structure, and had a variance parameter, which were approximately 21.7 as shown in the Table 5. The regression was able to explain the variation in the observed farm-gate milk price and hence, most of the coefficients from the regression equation were as expected and the study expectations met. The null hypothesis held that determinants of milk price heterogeneity have no significant effect on farm-gate milk price was thus rejected. The Inverse Mills ratio (IMR) or selectivity bias correlation factor had significant positive effect on the households' farm gate milk price per liter per day.

Results revealed that the number of milking cows was negatively associated with farm-gate milk price for those farmers who sold milk only to commercial milk buyers. As the number of milking cows increased per unit, the dairy farmer household received lower average farm gate milk price per liter per day. Regarding the estimated coefficient of distance, the coefficient negatively influenced farm gate milk price. Distance to milk buying points was associated with decrease in farm-gate milk price. A unit increase in distance to the milk market was associated with 19.20% decrease in farm-gate milk price. The lesser the milk price received by the dairy farmer, the more difficult and costly it would have been to get involved in the milk market. This was because most of the commercial milk buyers were located in trading

Table 1. Milking cows per farm household and by type of milk marketing channel (Authors' Estimates from Survey Data, 2016).

Number of milking cows	HHs selling milk only to commercial buyer(s)	HHs selling milk to final consumers only	HHs selling milk to both final consumers and commercial buyer(s)	Total
1	54	72	4	130
2	104	53	3	160
3	30	32	4	66
4	22	7	6	35
5	12	4	1	17
6 – 9	9	3	2	14
10 – 19	6	2	1	9
Above 20	1	0	0	1
Total	238	173	21	432
Mean = 2.6	SD =3.1	Minimum = 1	Maximum = 50	-

HH: Household.

Table 2. Milk price statistics for farmer households selling to both commercial buyers and final consumers (Authors' Estimates from Survey Data, 2016**)**.

All counties	Mean selling to commercial	Standard deviation	N	Mean selling to final consumers	Standard deviation
Average milk price received 2015 (KES)	35.51	6.93	194	41.65	8.44
Average milk price received 2014 (KES)	32.71	5.88	194	37.31	8.01
Average milk price actually 2013 (KES)	29.91	5.55	194	33.03	7.03

Table 3. Commercial farm gate milk buyers (Authors' Estimates from Survey Data, 2016).

Commercial farm gate milk buyer	No. of HHs	Mean price per liter	Standard deviation	Minimum	Maximum
New KCC	9	34.78	7.10	30	50
Brookside	14	33.93	7.32	27	50
Traders/Vendors	181	36.76	7.49	25	60
Milk buying Self-help groups	8	37.5	5.35	30	45
Milk cooling/chilling plants	61	33.34	6.67	26	60
Total	273	-	-	-	-

Table 4. Tests of fixed effects (Authors' Estimates from Survey Data, 2016).

Source	Numerator Df	Denominator df	F	Sig.
Number of farm gate commercial buyers	1	417.000	0.217	0.041
Number of milking cows	1	417.000	46.847	0.000
Distance to milk market	1	417.000	4.343	0.038
Total milk output sold via New KCC	1	417.000	0.003	0.057
Total milk output sold via Brookside	1	417.000	1.437	0.031
Total milk output sold via milk Traders	1	417.000	8.254	0.004
Total milk output sold via Self-help groups	1	417.000	0.209	0.048
Total milk output home consumption	1	417.000	5.556	0.019
Total milk output sold via milk cooling/chilling plants	1	417.000	0.338	0.561
IM Ratio	1	417.000	146.326	0.000
Trust	4	417.000	2.543	0.039
Intercept	1	0.000	40.011	0.000

Table 5. Determinants of farm gate milk price.

Parameter	Coefficients	Standard error	T	P>|t|
Number of milking cows	-0.889	0.1298	-6.845	0.000*
Distance to milk market	-0.192	0.0920	-2.084	0.038**
Number of farm gate commercial buyers	0.120	0.2982	-0.466	0.041**
Total milk output sold via New KCC	0.002	0.0360	0.054	0.957
Total milk output sold via Brookside	-0.032	0.0266	-1.199	0.231
Total milk output sold via milk Traders	0.038	0.0132	-2.873	0.004*
Total milk output sold via Self-help groups	0.019	0.0412	0.457	0.648
Total milk output home consumption	-0.077	0.0324	-2.357	0.019**
Total milk output sold via milk cooling/chilling plants	0.0095	0.0164	0.581	0.541
Trust	-0.878	0.363	-2.42	0.016**
Probability of random selection				
Inverse mills ratio (λ)	17.354	1.4346	12.097	0.000
Intercept	29.491	4.9598	5.946	0.000
Random effect and residual covariance				
Residual (variance/covariance)	51.4813	3.5653	-	0.000*
Intercept variance	21.7407	-	-	-
LR test vs. linear regression $chi^2(4)$	9.88	-	-	-
Log- restricted-likelihood	-1513.75	-	-	-
Prob > chi^2	0.043	-	-	-

Trust levels (5 Point Likert scale) – 1 = strongly disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = strongly agree. * = 1%, ** = 5%, and *** = 10% levels of significance. *p*-value of Likelihood Ratio Test ($Pr>x^2$). Source: Authors' Analytical Computation from Survey Data, 2016

centers and yet the majority dairy farmer households were in the villages. Ultimately, this may have become a limiting factor for farmers from such areas to sell more proportions of milk to commercial milk buyers. In addition, milk being a perishable product, dairy farmers feared the risk of losing their milk during long distance transportation in addition to high transport costs involved in formal milk marketing channels. This finding was in convergence with findings of Muricho (2015), who observed that as the distance increases away from the farm, there is a decline in the transacted quantities by farmers.

Output milk price received by dairy farmer households was also of considerable importance to this study. The number of farm gate commercial milk buyers' exerted positive and significant effect on farm gate milk price. Results showed that a unit increase in the number of commercial milk buyers was associated with a 12% increase in farm gate milk price per day. As expected, farmers that produced large volumes of milk receive better milk price for their milk supply because of the existing competition between the milk buyers. According to Swinnen and Maertens (2007), greater competition should lead to more equal rent sharing, evidenced by higher producer prices and more services for farmers. Farmers would receive less milk price when faced with a privately owned or government controlled monopoly as argued by Sadler and Good (2006). An improvement in milk price was expected to significantly lead to an increase in household income. This would have stimulated demand for varied household goods that would eventually lead to improvement of the welfare of the dairy farmer household. However, the number of commercial milk buyers may not have been an effective measure of competition particularly where there was collusion amongst the buyers.

Selling milk through milk traders as a determining factor presented a statistically significance and positive result on farm gate milk price per liter per day for farmer households selling milk to commercial milk buyers. The model predicted that an addition of one trader to the milk market would lead to an increase by 3.8% in the farm gate milk price per liter per day. This meant that the relationship level between commercial milk buying traders and dairy milk selling farmer households had positive significant affect on farm gate milk price in the long run. The sign of the coefficient was consistent with the expectations, that is, the higher the relationship between milk buying traders and dairy milk seller, the more the farmer would prefer the milk traders in the long run. Thus, the result was consistent with the hypothesis, indicating a preference for direct sales to milk traders by the dairy farmer households in return for better milk price. In the context of milk market liberalization and its consequences and off-farm/non-farm income opportunities being limited to most of the dairy farmers in Kericho County, positive association of selling milk through milk traders with farm gate milk price per liter per day was expected. Since liberation in Kenya, milk buying traders have become diversified. The sheer number of milk traders has led to buying and selling of milk to consumers in raw unprocessed or unpackaged form due to the consumers' unwillingness to pay the extra costs of processing and packaging. As a consequence, large numbers of milk traders enhances competition for milk supply, thereby increasing the family's daily income from milk sales. These milk markets may also provide valuable opportunities for rural and urban employment. However, unprocessed and unpackaged milk is prone to diseases which may be hazardous to the final consumers. Product quality was significantly linked to higher farm gate milk price.

Results on trust revealed a negative relationship with the actual milk price received by the dairy farmers. Although the coefficient of the factor trust showed negative sign (reject hypothesis), which would accept the formulated hypotheses on trust level, it was statistically significant, that is, it did have significant impact on farm gate milk price variability. The negative coefficient on trust by the smallholder dairy farmers on commercial milk buyer proved to be aligned with the expectations for farm gate milk sales price. A smallholder dairy farmer household saw the commercial milk buyer as the greatest source of knowledge about the farm gate milk price and understood that farm gate milk price provided by the commercial milk buyer may have been better in solving potential problems. When trust levels by dairy farmer on commercial milk buyers increased, the commercial buyer would eventually have no interest in him or her. However, given the statistical significance of the coefficient, this study concluded that the effects of trust interfered with farm gate milk price.

The Inverse Mills ratio (λ), which was a correction factor for selectivity bias, was significant and depicted that there were unobserved factors that would have affected the selection (milk marketing channel choice price) as well as the outcome (marketed milk surplus) equation.

CONCLUSIONS AND POLICY IMPLICATIONS

This paper analyzed the determinants of milk price heterogeneity in dairy farmer household farms in Kericho County, Kenya using multivariate probit and selectivity bias mixed-effects linear regression model. Post-hoc pair wise comparisons on mean milk price heterogeneity at farm-gate received in all the six sub-counties was partially supported. Mean milk price received by dairy farmer households in 2013 was significantly better than the mean milk price received in 2014. Based on the selectivity bias mixed-effects linear regression model, results revealed that the number of milking cows, distance to milk market and trust on commercial milk buyer by seller were statistically significant. However, the factors were associated with decrease in farm-gate milk price per liter per day. Farm gate commercial milk buyers and percent total milk output sold via milk traders were the main determinants of variability in farm gate milk price per liter per day for the farmer households that sold milk to commercial buyers only. The other remaining factors were not identified statistically as determinants of variability in farm gate milk price per liter per day. In conclusion, the present study contributes to our theoretical understanding by showing that the development of factor relationship characteristics may influence the choice decision of a smallholder dairy farmer milk seller, but a commercial milk marketing channel choice may not always be the first option for the dairy milk farmer household. The welfare of the smallholder dairy farmer therefore depends on the milk price received for their daily milk output. Besides being a valuable source of income for rural dairy farmer households in Kericho County, dairy milk production also helps in smoothing household incomes, which in turn smoothens consumption hence improving farmer household welfare over long periods of time. Financial, market access and market involvement seems to be very important factors affecting farm gate milk price per day. Thus, local county government and national governments could pay more attention to enhance dairy farmer household access to milk markets and financial investment. In future relevant stakeholders should redesign or reform milk marketing implementation strategies or improve/strengthen existing milk marketing policy.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Differential impacts of an irrigation project: Case study of the Swar Dam Project in Yedashe, Bago region of Myanmar

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In Myanmar, the government has made a vast investment in the construction of dams to improve crop productivity and to ensure socioeconomic development. This study explores the differential impacts, in terms of socioeconomic conditions, of these investments for paddy farmers in Yedashe Township, in the Bago region in the south-central part of Myanmar. A farm survey among 95 respondents is used to compare the situation before and after the construction of a dam. It is observed that after the installation of the dam, the farmers could practice double rice cropping enabling them to gain higher income. The impact of the dam project on the employment rate, paddy yields and incomes were measured using normalized vector equations. A positive effect on all these factors was observed. The incomes of the farmers increased by benefiting from higher crop productivity, more crops per year, and more benefits over variable costs. However, the return above variable cash costs (RAVCC) and the benefit over cost (BC) ratio of head-end users was significantly higher than that of middle-reach and tail-end users. Therefore, the study additionally explored the problems of unequal water access and farmer-oriented solutions to these problems. The lack of monitoring and management of the irrigation institutions was found to be a major constraint for the development of the irrigation sector. Therefore, efficient utilisation of irrigation water by water-users, and policies as well as investments in the development of irrigation infrastructure need to be emphasised.

Key words: Irrigation dam, downscaled water users, disequilibrium, impact assessment.

INTRODUCTION

Myanmar is one of the largest countries in South-East Asia with a total area of 676, 577 km². The total population is nearly 52.42 million with an annual population growth of 1.01%. The agricultural sector is the backbone of Myanmar's economy, and it contributes 26% (2011 to 2012) to the gross domestic product (GDP); it

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represents 16.4% of total export earning; and it employs 61.2% of the labour force. About 40 million people (nearly 66% of total population) live in rural areas and their livelihoods depend on agriculture or related income sources (DAP, 2013; DAP, 2014). The agricultural sector in Myanmar is dominated by paddy cultivation.

The production of rice relies on a favourable ecosystem with adequate water supply. Irrigation water availability therefore is an important and essential part for the production of rice (Bouman, 2012). In Myanmar, access to irrigation water for rice cultivation is particularly crucial during the dry season (Naing et al., 2008; Naing, 2011). Therefore, governments have included construction of irrigation facilities in their regional development plans (Zaw et al., 2011). Past and present governments have invested in water resource management through storage of water in dams or reservoirs. Up to now, 241 dams have been constructed to increase irrigated crop production throughout the nation, and to control flooding (DAP, 2013; DAP, 2014).

With the increasing scarcity of water resources, investments in water availability and water management facilities are becoming essential for many countries. For the implementation and monitoring of equitable water distribution, sufficient collective action is required to promise an efficient water use and maintenance of the quality of irrigation canals (Meinzen-Dick et al., 2002). The overall benefits of improved irrigation facilities and its related externalities for the society should be studied.

This requires assessing the complex adjustment of social, biophysical and economic factors. Such assessment is also necessary for Myanmar (Naing, 2011). In order to accurately evaluate the effect of irrigation, it is needed to assess the corresponding economic consequences (Paredes et al., 2014).

The construction and rehabilitation of irrigation systems basically aims to increase rice production, and to have sufficient production of other crops. The general benefit of these systems extends over different sectors in Myanmar. However, because of a lack of systematic management of the dam and the lack of proper management of irrigation canals as well as a failure of monitoring and policy implementations by the irrigation sectors in Myanmar, water demand is not met throughout the growing season. The rice yields are unstable and falling due to insufficient water access in the later maturity stages of rice mainly for the tail-end rice growers (Naing, 2011). In this context, it is relevant to study the effect of irrigation on different water users and to compare the benefits and costs for the irrigated farms.

In Myanmar, water users groups (WUGs) and water users associations (WUAs) play an important role in the management of irrigation water and the development of irrigation dams. However these organisations still do not function well. Lack of proper monitoring, control and maintenance of the dam and the irrigation system leads to decreasing water supply for downstream water users, to a deterioration of the irrigation system, and a defective water control. This, in turn, tends to diminish the irrigated area and final crop production.

Therefore, with the aging of the irrigation dams it is also relevant to evaluate whether the irrigation facilities are still able to meet the water demands of the farmers. Due to the lack of assessment of the costs and benefits of dam projects in Myanmar, the roles of dams in rural development as well as the livelihood impacts are still unclear. And thus, the assessment of the impact of irrigation dams on the socioeconomic conditions of rice growers should be a critical topic for the rural development in Myanmar. The present research aims to assess the direct impact of the construction of a dam on employment, yield and income of paddy farmers in Yedashe Township, Bago region in the southern central part of Myanmar.

CONCEPTUAL FRAMEWORK

The assessment of the benefits and the costs of irrigation dam investments, deals with evaluating the economic value and societal benefits brought by this intervention. This economic impact assessment should include several sectorial linkages such as changes in productivity, changes in cropping patterns, changes in microeconomic variables like employment rate, changes in cost-benefit ratios, and changes in related crop incomes. Such an extensive assessment is necessary as large-scale irrigation development is usually initiated in view of a broad socioeconomic and regional development, and has an impact on many other sectors of economy too (Hussain and Bhattarai, 2002).

The significant impact of irrigation projects on society through several social aspects such as households conditions, educational level, social welfare expenditures, and overall livelihood development and poverty reduction were observed by many authors (Turral et al., 2010; Khan and Shah, 2012; Kresovic et al., 2014, Wichelns, 2014).

In this study, we assumed that the introduction of the Swar dam project might affect the social and economic characteristics of paddy farmers in the following ways:

(1) Receiving of irrigation water from the Swar dam may indirectly improve farm incomes by improving agricultural practices, in terms of changing cropping intensity and cropping patterns, and increasing paddy production.
(2) The Swar dam project might indirectly affect society in many ways. It may have impacts on the educational level, livelihoods assets, household’ expenditures, different forms of social relationship and coherence. The impact of the dam on for example conflicts between irrigators, on inequality of water access needs to be assessed.

Irrigation projects and their related activities can also have environmental impacts: it may for instance lead to soil and water pollution. Such environmental impacts are however beyond the scope of this study.

Therefore, this study hypothesizes that farm incomes of the paddy farmers change after the instalment of the irrigation dam and that it is expected that there are differences in paddy yields and profits of the farmers before and after the instalment of the Swar dam. As mentioned before, not all farmers in the Yedashe Township have full access to irrigation water for their farming practices. We therefore also focused on problems of irrigation water availability. In this perspective, the Swar dam was selected to assess the effects of an irrigation dam on crop production and on the socioeconomic characteristics of farmers located at different distances from the dam in Yedashe Township in Myanmar. This study may highlight institutional characteristics and constraints in using irrigation water from the Swar dam. It also looked at coping strategies of farmers to assure adequate irrigation water supply for paddy production.

MATERIALS AND METHODS

Study area

The study was performed in the Yedashe Township, which is located on the northern edge of the Bago region. The Bago region is the second most important production area of rice after the delta region and it is a lowland irrigated rice production region in the south- central part of Myanmar. The annual rainfall in this region is about 2513 mm with 78.5% of mean relative humidity (DAP, 2013). The Yedashe Township is located between 95°50' to 96°30' East longitude and 19°5' to 19°30' North latitude. This region is part of the central plains ranging from South to North, and is bounded in the West by the Yoma mountain range and in the far East by the Shan mountain range. There are 19 village tracts that receive irrigation water from the Swar dam (Figure 1).

Four village tracts namely Kwingyi, Thapyaytan, Konegyi and Doetan were selected and the basic statistics of the selected village tracts are presented in Table 1. The total land area is about 3300 hectare of which 83% approximately 2757 hectare is cultivated with rice. In 2014 the total population was approximately 11500. The annual production area for paddy was about 2700 ha under monsoon production and 2150 ha under summer production (Table 1).

Paddy is a major crop in Yedashe Township and covers about 32991 hectare. In Figure 2, the production area of monsoon and summer rice is presented. In the past, summer rice was cultivated with residual water from monsoon precipitation. A sharp increase in the production areas of summer rice was observed after the instalment of the Swar irrigation dam in 2003. However, the rice yields are found to be very unstable and relatively low. The average rice yield is 607 kg per hectare in monsoon season and about 625 kg per hectare in the summer season[1].

[1]Source: Department of Agriculture, Yedashe Township, Bago Region, Myanmar (2014)

Agro-ecological condition

The Yedashe Township has a tropical monsoon climate. There are three distinct seasons in Myanmar, summer season (March to April), rainy season (May to October) and the cold and dry winter season (November to February). The Yedashe Township has an average elevation of 12 meter above sea level. In the summer period, the average temperature is 38°C at noon, but in the winter season, the average night temperature is about 15°C. The 20 years rainfall data showed a mean precipitation of 2038 mm (±395 mm), and the mean number of days with precipitation was observed to be 97 days (±11 days) in the study area. In the wet season, the highest rainfall peak can be observed in July.

Sometimes, the peak is delayed until late September. In the summer season, the extremely weather events make it difficult to cultivate the rice.

Sampling and data collection

The study was conducted with paddy farmers in the Swar dam project areas in Yedashe Township. Four village tracts out of the nineteen village tracts were purposively selected because these village tracts are strategically located. Based on their location, three irrigation water user strata can be identified: head-end users, middle users, and tail-end users.

During the selection of the four village tracts, the suggestions of the Township Agricultural Service workers, and field team leaders were acquired, but in the end the data was sourced from a random survey. The four tracts Kwingyi, Thapyaytan, Konegyi and Doetan have received irrigation water from the Swar Dam since the project started in 2003. The fieldwork was conducted from April to May 2014. The Kwingyi village was located close to the dam and its inhabitants are regarded as head-end users. The Thapyaytan and Konegyi village tracts were located somewhere around the middle and inhabitants are therefore recorded as the middle reach users (Table 2).

The Doetan village tract was situated the furthest from the Swar dam. This is where the irrigation canal from the dam project stops. The inhabitants of this village are considered as tail-end users. The questionnaire covering the socio-economic characteristics of farm households such as incomes, family size, and other relevant variables as well as farm productivity, and problems and solutions related to water availability from the dam were prepared. A face-to-face interview was carried out with farmers and data were obtained from the farmers. In total, 24 head-end users, 44 middle-reach users and 27 tail-end users were interviewed (Table 2).

Direct impact assessment

Cost-benefit analysis is widely used in economic analysis and a vast majority of methods are applied. It is used to assess the profitability of an investment or a certain project. This can help to decide whether additional funding for the operation or extension of the project must be obtained (Patah and de Carvalho, 2007). But, the direct impact assessment is a simple way of assessing the correspondent impact of activities.

The direct impact of increased irrigation water availability on the production, farm incomes, and employment rate can be evaluated by using normalized vectors of these variables (Martinez et al., 2013). The direct impact caused by the instalment of the Swar dam on the income of the paddy farmers (***Vinc***), on the production capacity (***Vr.inc***), and on the employment rate (***Vemp***) can then be expressed as follows:

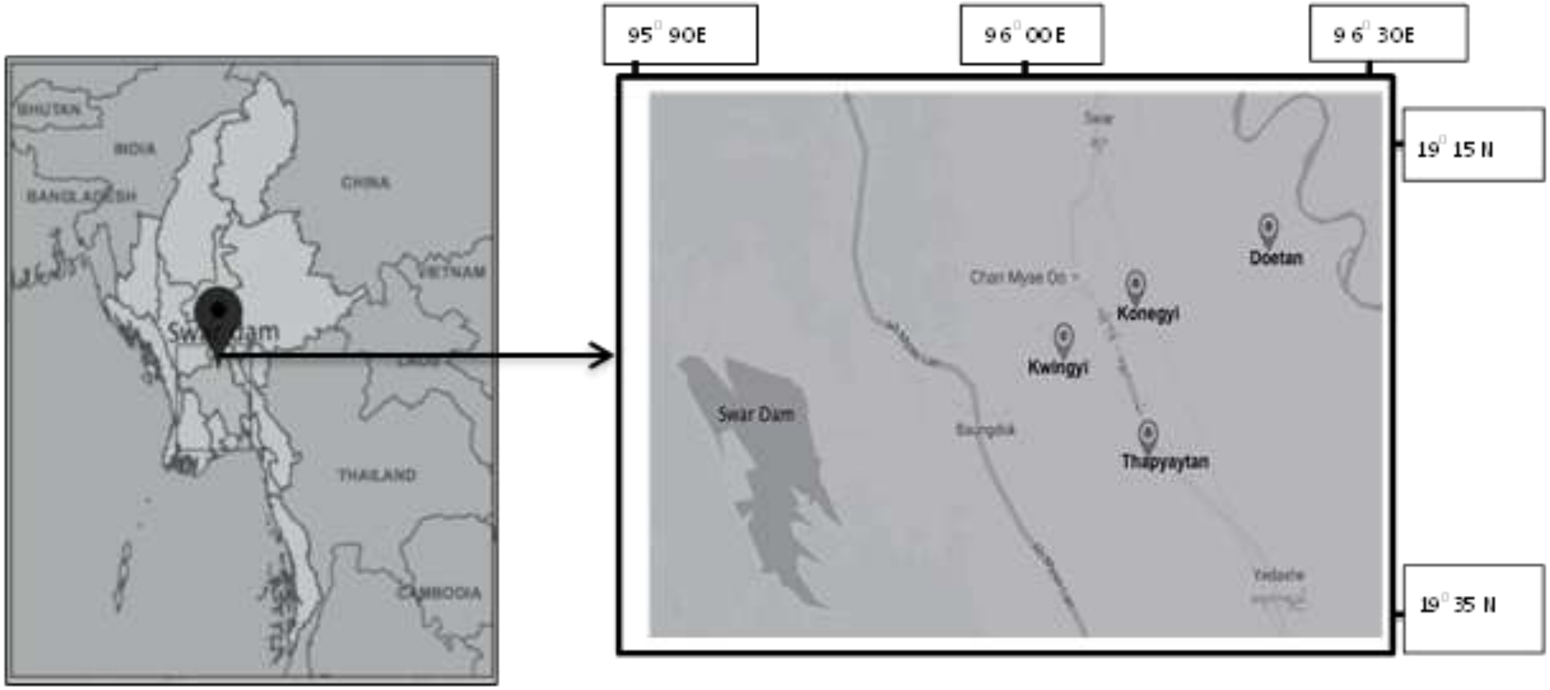

Figure 1. Map showing sampling areas and location of Swar irrigation dam in Yedashe Township (Source: Acknowledgement of the MIMU[2]).

Table 1. Four selected rice production village tracts under the Swar dam project.

Village track	Number of households	Total cultivated land (ha)	Rice cultivable area (ha)	Monsoon rice production area (ha)	Summer rice production area after the instalment of Swar dam (ha)	Total population		
						Male	Female	Total
Kwingyi	437	626.453	595.697	542.278	555.633	1095	1093	2188
Thapyaytan	390	834.462	773.759	773.759	733.290	826	891	1717
Konegyi	661	904.877	690.798	690.798	597.316	1645	1714	3359
Doetan	898	921.064	715.079	715.079	263.045	1998	2227	4225
Total	2386	3445.898	2757.123	2721.915	2149.285	5564	5925	11489

[2] Myanmar Information and Management Unit

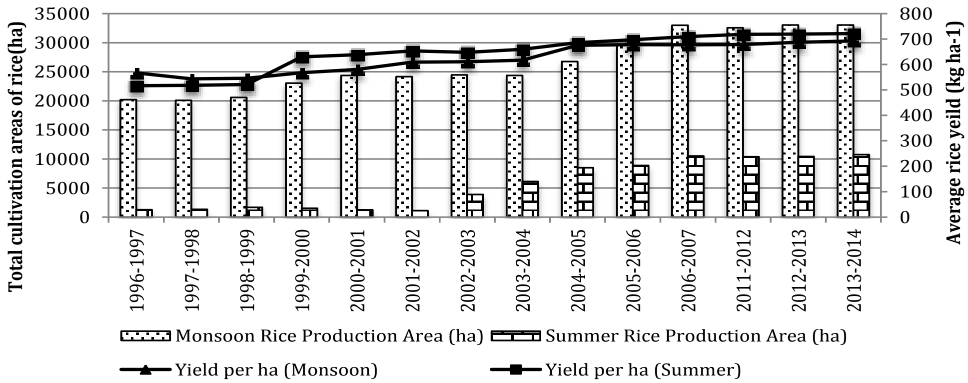

Figure 2. Total area of rice production and average yield (kg ha^{-1}) in the study area.

Table 2. Sampling of respondents from different group of the water users.

Village tract	Number of villages	Selected households	Water users	Percentage (%)
Kwingyi	5	24	Head-end User	25.3
Thapyaytan	3	21	Middle reach User	46.3
Konegyi	6	23		
Doetan	5	27	Tail-end User	28.4
Total	19	95	-	100.0

$$\Delta Vinc = wnr\Delta X$$
$$\Delta Vr.inc = Rnr\Delta X$$
$$\Delta Vemp = enr\Delta X$$

Where, w_{nr}, R_{nr} and e_{nr} are respectively the normalized vectors of income changes, production capacity changes, and changes in employment with the elements $wnr_i = w_i/x_i$, $Rnr_i = R_i/x_i$, **and** $enr_i = e_i/x_i$, respectively. Here, (X) factor represents the total output, ***'i'*** represent the capacity of the sector, and ***'x'*** represents the output of each sector.

This study assumed that farmers make a series of production choices aimed at maximizing profit at farm level and the farm households, however, are price takers and hence individual farmers have no impact on market prices. Hemson et al. (2008) addressed that a market-pricing method is suitable for financial or private cost-benefit analysis. To avoid the variation in market price, this study used the current market prices for the comparison of costs and benefits of paddy production between the situation "before" and "after" the instalment of the dam.

However, the aggregate net revenue per hectare (€ ha^{-1}) depends upon the output of rice crop, input prices and purchased inputs. Therefore, in the calculation of the benefits and costs, the change in productivity method can be used alternatively to derive the imputed value by providing the prices of other inputs and outputs. In the study, descriptive analysis, cost-benefit analysis, as well as a functional analysis was included.

Productivity and sensitivity analysis

In irrigated crop production, water is used as an input and thus the value of water can be derived indirectly using the economic concept of the production function. This is known as the change in productivity method, or residual imputation method, or change in net income method, which can be used to derive the shadow price of water, when knowing the prices for other inputs and outputs (Hussain and Bhattarai, 2002). The change in productivity method equation can be presented as follow:

Benefit or Value of Irrigation Water= $NVO_w - NVO_{wo}$;

Then, $NVO_w = GVO_w - C_w$, *and*

$NVO_{wo} = GVO_{wo} - C_{wo}$

Where, '*NVO'* is the net value of output, '*GVO'* is the gross value of output, '*C'* is the total cost of production, *subscript 'w' and 'wo'* represent with and without the irrigation water from the dam. The traditional cost-benefit analysis is often used as a tool for impact assessment, but it is very sensitive to the quantities and prices of inputs used in the production processes (Hussain and Bhattarai, 2002).

In this case, a sensitivity analysis can be apportioned to different sources of uncertainty in its inputs. Sensitivity analysis deals with the change in the quantity of total physical product resulting from a unit change in a variable input, keeping all other inputs unchanged. It studies the change in the quantity of total physical product resulting from a unit change in a variable input, keeping all other inputs unchanged (Komleh et al., 2011). The rice production functions in the study area were calculated according to Zangeneh et al. *(*2010) and Komleh et al. (2011).

Hussain and Bhattarai (2002) state that the change in cropping intensity and the interaction with an irrigation intervention could attribute directly to the benefits of irrigation. In order to determine the benefits in terms of farmers' income, the benefit over cost ratio and the return over variable cash costs were also calculated. The benefit-cost ratio (BC) is commonly used in cost-benefit analysis and expresses in monetary terms the overall value of a project. The BC takes into account the amount of benefits or gains by performing a project and the costs to execute it. The benefit over cost ratio is calculated according to Komleh et al. (2011).

Overall, the assessment of the impact of a project can be evaluated using several methods, including cost-benefit analysis, productivity analysis, sensitivity analysis, etc. Each method has its own strengths and weaknesses. Therefore this study combined varies methods to give a reliable and holistic picture.

RESULTS

Socio-demographic characteristics and impact of irrigation water availability

The socio-demographic characteristics of the water user groups are provided in Table 3. The average age of the farmers in the study area did not differ a lot over the three groups and ranged from 51 years to 56 years. Farming experience determines the skills and the efficiency of the individual farmer to produce a certain output. In the study area, the mean farming experience of the farmers was above 29 years, and average family size was around 4.

The direct impact of extended irrigation water availability on the production functions, farm incomes and employment rate were calculated by the normalized vectors of unit change equations. Crop production requires labour input throughout the production process. The results indicate that the normalized vector values of change in employment rate for the head-end user was an average vector unit of 0.375 before the construction of the dam and about 0.667 after the intervention. The change in employment rate increased also for middle-reach users and tail-end users (Table 4).

The production capacity of the paddy famers also increased. An increase in paddy yield of the head-end users, middle-reach users and tail-end users' was observed. Due to the improvement in production capacity and gross output, the income of paddy farmers increased. After the construction of dam, the change in farmer's income was observed with an average increase of about 3 times higher in all the water users.

Production input of the paddy farmers

In Myanmar, agricultural sector heavily relied on farm laborers and draught cattle for land preparation, weeding, fertilization, water management and harvesting, as agricultural mechanization was not yet developed much (Naing et al., 2008).

In irrigated regions, several farming activities generate employment for the local people. Before the dam project, farm' households were not possible to achieve year round employment in the study areas. Due to the availability of irrigation water from the dam, farm' households are now able to cultivate paddy and other cash crops in their farms.

Therefore, the intensification of agriculture through double cropping patterns is a solution to achieve year round employment opportunities. In this study, the average family labor input used on a day basic (men per day) in the paddy production processes under single cropping season (before) and double cropping season (after) was estimated.

In Table 5, the mean family labour used before the project was 1.5 men day^{-1} among the head-end users and it was 1.708 men day^{-1} after the project. It is evident that after the irrigation dam project, the mean family labour inputs increased in all the water users groups and more men power is used on the farm, as summer rice cultivable is now possible.

Based on the differences between the situation before and after the instalment of the irrigation dam, the comparison of the costs and benefits of monsoon rice production among different water users is presented in Table 6. The average farm output of each individual farmer was calculated based on a cumulative productivity of paddy crop on a hectare basic.

Therefore, the differences in price of the water user groups were observed because the farm benefit (€ ha^{-1}) of each water user group was calculated on a basic of differences in yield return. The total costs of production of monsoon paddy was around 209 € ha^{-1} on average for both the head-end and middle reach user groups and 220€ ha^{-1} for the tail-end users before the dam project.

The farmer's fixed costs (non- cash cost) such as owned cattle and manure cost, their storage seeds, and family labor costs were considered and variable costs (cash cost) such as hired cattle, farm-machines and labor cost, purchased manure, fertilizer, and pesticide costs were included in the total farmers costs for the paddy production and calculated on a hectare basic. More cash and non-cash costs of production of paddy crop was observed after the dam project, and the total costs of production increased to a mean value of 242, 261 and 267 € ha^{-1} for the head-end users, middle water users, and tail-end users, respectively. The summer rice production costs were comparable among the three different water users and 267, 260 and 242 € ha^{-1}, respectively (Table 6).

Farm income and paddy production

The study highlighted not only the differences in farm income before and after the dam project but also the income differences between different water users. The study found that an average monsoon paddy yield of

Table 3. Social demographic characters of the different water users.

Social demographic characters	Head end users (n=24)	Middle reach users (n=44)	Tail-end users (n=27)
Age (year)	56.9	51.3	53.0
Min	40	26	28
Max	80	87	83
Farming experience (year)	29.7	30.1	31.4
Min	25	8	10
Max	45	63	61
Family size (mean number)	4.5	4.5	4.2
Mean number of male	2.7	2.1	2.1
Mean number of female	2.2	2.5	2.1

Table 4. Direct impacts of irrigation water availability: Comparison of the situation before and after the Dam project.

Normalized vector of changes	Head end users (n=24)		Middle reach users (n=44)		Tail-end users (n=27)	
	Before	After	Before	After	Before	After
Employment (labour per unit change)	0.375	0.667	0.103	0.307	0.389	0.796
Yield (€ per unit change)	8.019	8.853	4.508	5.098	5.539	6.095
Income unit (€ per unit)	0.389	1.388	0.433	1.432	0.420	1.421

Table 5. Comparison of mean family labor input under before and after the instalment of Swar dam.

Family labor input used in the paddy production	Head end users (n=24)	Middle reach users (n=44)	Tail-end users (n=27)	F-test
Family labor before the dam project (men day^{-1})	1.5	1.25	1.148	3.245 (0.043**)
Family labor after the dam project (men day^{-1})	1.708	1.386	1.593	1.779 (0.175)

3084 kg per hectare of paddy crop was found before the dam project and an average monsoon paddy yield of 3293 kg per hectare was observed after the dam project.

In summer, rice production, an average of 3447 kg per hectare of higher yield was observed. Therefore, a significant yield difference was observed before and after the instalment of irrigation dam. The study also observed that the average net farm income of the head-end and middle-reach users are respectively around 245 and 240 €/ha, which is much higher than that of the tail-end users (208 €/ha). Thus, irrigation can increase the annual benefits and farm income of farmers, but differences in water availability causes a spatial income differentiation. In order to clarify the benefits of the farmers' income, benefit over cost (BC) ratio and the return above variable cash cost (RAVCC) were additionally established.

According to the results, the RAVCC of the monsoon paddy production also increased after the introduction of the dam project, from 176 €/ha to 292 €/ha for the head-end users, from 179 €/ha to 282 €/ha for the middle water users, and like 180 €/ha to 256 €/ha for the tail-end users.

This increase was statistically significant at 1% level with the paired sampled T-test. Irrigation intervention makes it possible to intensify the production of paddy crop in the study area. Before the dam project, the average cropping intensity of sampled farmers was about 109.4 units and almost doubled to 205.8 units after the dam project. For the summer rice production season, the BC ratio and RAVCC were compared among the different water users. The BC ratio and RAVCC of the different water users for the summer rice production, was higher than that for monsoon rice production.

This increase was statistically significant at 1% level with the paired sampled T-test. The study also showed that the cropping intensity ratio of the head-end, middle-reach and tail-end farmers increased after the instalment of Swar irrigation dam. In this way, the household income increased by benefiting from more output per crop, more crops per year, and ensuring more return over variable

Table 6. Paddy productions and income functions: before and after the dam project.

Benefit/Cost of production	Input/output	Before the dam project (Monsoon rice)			After the dam project (Monsoon rice)			After the dam project (Summer rice)		
		Head end users (n=24)	Middle reach users (n=44)	Tail-end users (n=27)	Head end users (n=24)	Middle reach users (n=44)	Tail-end users (n=27)	Head end users (n=24)	Middle reach users (n=44)	Tail-end users (n=27)
Benefit of production	Total farm income (€/ha)	143	142	138	245	240	208	289	275	253
	F-test		0.121			5.117**			3.289**	
	Yield (ton/ha)	3.36	3.38	3.46	3.67	3.55	3.67	3.89	3.79	3.72
	F-test		0.754			1.861			5.64***	
	Market price (€/ha)	105	104	104	133	141	130	137	141	140
	F-test		0.956			28.279***			3.155**	
	Gross benefit (€/ha)	352	351	358	487	499	457	530	536	521
	F-test		0.438			2.457*			1.862	
Cost of production	Total cost (€/ha)	209	209	220	241	260	267	242	261	267
	F-test		2.825*			13.819***			13.82***	
	Non-cash cost (€/ha)	32	37	41	47	43	48	47	43	48
	F-test		29.485***			7.681***			7.681***	
	Cash cost (€/ha)	177	172	179	194	217	219	194	217	219
	F-test		1.233			16.95***			16.953***	
Benefit over cost (BC) ratio	BC	1.705	1.693	1.633	2.024	1.974	1.781	2.209	2.056	1.948
	F-test		0.844			8.615***			6.824***	
Return above variable cash cost (RAVCC)	RAVCC (€/ha)	175	179	180	292	282	256	335	321	275
	F-test		0.104			4.544**			8.529***	
Cropping intensity (CI)	CI	106.2	108.3	114.0	203.8	203.532	211.531	203.75	203.5	211.53
	F-test		0.944			1.407			1.407	

*** = Values statistically significant at 0.01 probability level, ** = values statistically significant at 0.05 probability level, * = values statistically significant at 0.10 probability level.

costs.

Farmers' perception to problems and solutions related to the Swar dam

In this study, qualitative data assessed farmers' responses to water availability problems. Water availability is considered sufficient if it leads to the successful production of rice without water deficit. Water availability is considered low when there is limited availability of irrigation water from the Swar dam in the rice production season (Figure 3).

The study found that 51.9% of the tail-end users faced low water availability, while 54.2% of head-end users reported sufficient water availability as shown in Figure 3. 50% of the middle-reach users observed moderate water availability, while in the tail-end region, no farmers reported sufficient

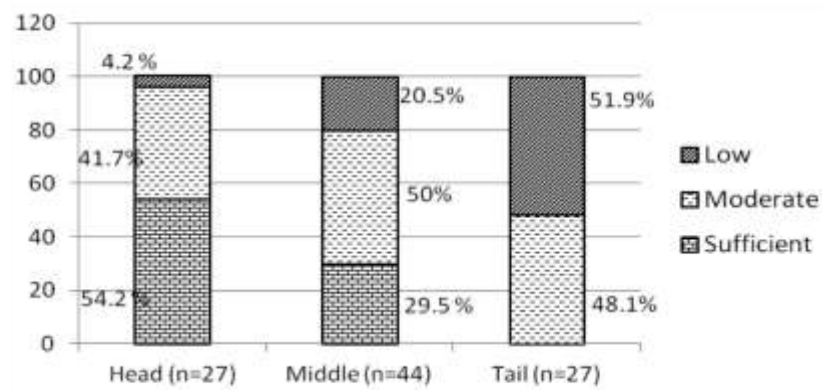

Figure 3. Water users' perspective on irrigation water availability.

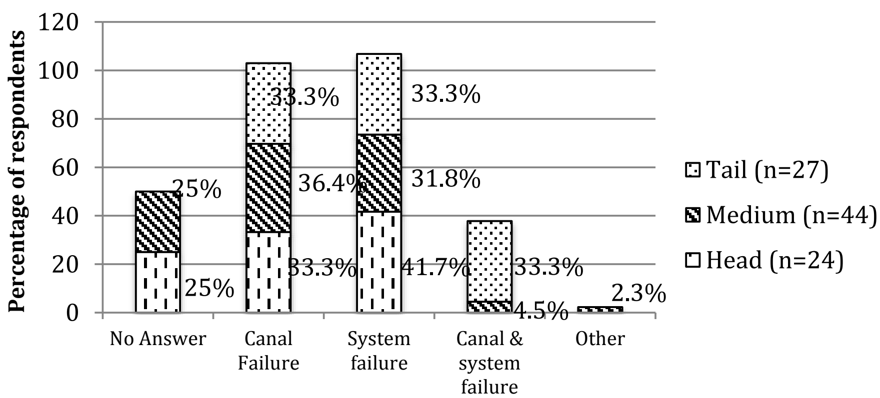

Figure 4. Problem reported by water users of the Swar Dam Project.

water availability.

Farmers' perception on the causes of water unavailability is given in Figure 4, 41.7% of the head-end users reported that insufficient water availability is experienced due to mismanagement of water distribution. 25% of the head-end and middle reach farmers did not report any causes. From both middle-reach users and tail-end users, about over 30% reported the canal failures and water system mismanagement are the major problems.

Farmers finally suggested solutions to improve water availability. Of the tail-end farmers, 48.1% mentioned that better water allocation is needed to improve water availability on their farms. They believe that an inadequate water distribution system is responsible for their water shortage. A better maintenance of the dam is required following 50% of the middle-reach users and 58.3 % of the head-end users, while a further 25 % of these users see an improvement of the irrigation canals as a major solution. As a results, 18.2% of the middle-reach farmers and 16.7% of head-end farmers reported yield fluctuations in the previous five years; while all of the tail-end users mentioned that their crop yields highly fluctuated.

DISCUSSIONS

The study's limitations

This study was to assess the impact of the Swar dam project on different groups of farmers, and the changes in the socioeconomic status of paddy farmers. One of the limitations of the study is related to the before and after comparison. It was difficult for farmers to remember input use and income activities.

To overcome this, we used the "Record of Production of Individual Farmers"[3]. The study considered the farming productivity of farmers in the past ten years as a basis.

[3] This book is commonly called 'the farmers' book" that record the paddy-sown acres, total output in yield, and the procurement quota for each year. This book is available amongst every farmer in Myanmar. (see also: *Okamoto, I (2008), Economic disparity in rural Myanmar: Transformation under Market Liberalization. Singapore: NUS Press/IDE-JETRO.*)

The fact that the townships' agricultural staff accompanied the researcher during data collection, and also improved collaboration of farmers. Furthermore, while it is not always easy to get access to secondary data or statistical data at the Township' Agricultural service and administration department, a recommendation letter by the regional administrator was helpful to get permission to access such secondary data.

Therefore by random sampling, having patience and spending a lot of time with the local farmers, regional agricultural professionals, servicing persons and by using different forms of assessing socioeconomic characteristics, data limitations could be minimized. This approach ensured to get more reliable data, and to produce valid results.

Irrigation and production input

In the study, the farm input was calculated based on fixed and variable production costs. Fixed costs were the farmer-covered cost or owned assets contributing to farm production. Fixed costs included owned draught animals for land preparation, family labour input, and manure obtained from owned animal, and storage of seeds for cultivation processes. The variable cost for agricultural production were such as number of cattle hired, additional labour input (non-family members), purchased manure loads, amount of urea and compound fertilisation bought / obtained, tractor or machines used for threshing and land levelling, and amount of pesticide used**.**

In both cases, the amount of fixed costs like farmer' owned cattle input, manure, family labor, and farmers owned-seed as well as variable costs like hiring cattle for ploughing, farm labor, and purchased manure, fertilizers and pesticides were calculated per hectare basic for each production type. The fixed costs of paddy production increased for all the different water user groups after the dam project.

As agriculture contributes greatly to employment opportunities in Myanmar, the problem of unemployment is normally higher in the off-season. This is because after the dam project, more family labor, farmer's owned cattle and manure inputs were used in the production of paddy crop, as double rice cropping is now possible in the study areas. The variable costs such as hired cattle, and hired labour also increased after the dam project as these inputs were more competitive at farm level and the price of hiring cattle and labor was expensive than before. In the study areas, when farmers have sufficient water supply, they can grow additional cash crops and practice intensive farming system to increase their family incomes. And hence, the productivity of land and labour is enhanced in the irrigated areas which contributes to higher household' incomes. Therefore our study confirms that agricultural water management generates local employment opportunities and provides a critical input to successful agricultural production as well as it enhances farmers' incomes which contributes to social and economic welfare of the farmers.

Farm income through irrigation

The direct impact assessment of this study showed that the irrigated summer rice production created more employment opportunities, higher farm incomes and higher yields. People residing nearby irrigation dams, can earn sufficient income from farm-related activities. Due to the introduction of an irrigation dam, the average farm labour in the agricultural production processes was increased as double rice crop production was possible which is comparable to the situation before the dam project.

Moreover, farmers are now possible to earn more income from alternative income sources derived from the sales of vegetables and fruits crops, production of food crops as well as incomes from the livestock rearing in the study areas. Accordingly, water availability through the instalment of dam inevitability benefited the local labour economy in many ways, especially by generating both farm and off-farm employment opportunities.

In general, the average yield of the summer paddy was higher than the monsoon paddy yield. However, also the average yield of monsoon rice farmers after the dam project intervention was higher than that of monsoon rice farmers before the dam project. Therefore, the study is agreed with Wichelns (2014) mentioned that the potential yield of grains are much higher under irrigation than in monsoon or rain-fed agriculture. Before the dam project intervention, farmers were solely depending on the production of monsoon or rain-fed rice. The study shows that in the monsoon season the average net farm income of farmers after the dam project was about 232 €/ha, while the average net income before the dam project was around 140 €/ha. Thus the irrigation dam project intervention increases the farm income through yield increases.

In addition, the benefit over cost ratio of the head-end users was higher than that of middle and tail-end users both in summer and monsoon paddy production. However, the different in the RAVCC and BC of the water users were observed after the introduction of the dam. The findings are consistent with Amarasinghe et al. (2008) that the benefit-cost ratio is much higher in head-end users because the net crop production benefit may vary across the canal reach.

After an irrigation dam intervention, although the contribution of production inputs could improve paddy crop productivity, some may argue that the presence of irrigation dam alone would not increase the productivity. For the reason, Hussain and Bhattarai (2002) mentioned that the measurement on cropping intensity and the interaction of an irrigation intervention could attribute directly the benefit of irrigation.

The study results show that the cropping intensity ratio of the head-end, middle and tail-end users was increased almost double after the dam project intervention. Due to the intervention of the irrigation dam, farmers could practice double rice cropping pattern as well as enable to cultivate other food crops, vegetables and fruits crops in the study areas. In this way, household income is increased by benefiting more output per crop, more crops per year, and ensuring more return over variable costs with irrigation.

Constraints and amelioration of the Swar Dam

Water access inequality problems usually occur due to failures in the management of the irrigation system. Several research findings underlined the importance of irrigation for the socioeconomic conditions of farmers (Hanjra et al., 2009; Burney and Naylor, 2012; Giordano et al., 2012; Domenech and Ringler, 2013), and the difference in the socioeconomic characteristics of the different water users depending on the availability of water (Amarasinghe et al., 2008; D'Exelle et al., 2012; Kresovic et al., 2014).

Farmers reported destruction of canals and unfair and untimely distribution of irrigation water by the irrigation department as major problems. The Swar irrigation project has been running for a decade and the canals are in a bad state. In the study areas, the uncontrolled actions of the farmers such as blocking the canal and pumping out the water destroyed the earthen-type canals. The tail-end users face lack of access due to such canal closures or due to the head-end users' priority behaviour.

Often farmers see their seedling nursery destroyed by a lack of water and thus the production costs are increased because they have to restart nurturing. This happens due to a lack of systematic management and monitoring of the irrigation system. In the study, farmers in the tail-end region face severe water shortages in summer paddy production. The production capacity and gross farm income of tail-end farmers were lower than that of the middle-reach and head-end users. Therefore, effective coordination between the farmers and local authorities could remove the problem of water shortage.

This should focus on maintenance of infrastructure, enhancing the exchange of ideas, knowledge and new technologies.

CONCLUSIONS AND RECOMMENDATIONS

This study was performed among 95 households from four village tracts benefiting from the Swar irrigation dam in Yedashe Township in Myanmar. By using normalized vector equations, the direct impact of the construction of the dam on employment, yield and income was estimated and it was observed that the mean vector of changes of these functions were higher after the dam construction than before.

The study also found that the RAVCC of the farmers increased after the dam project and also the BC ratio improved. Therefore, we conclude that irrigation increases the production capacity of the paddy farmers, and assists more benefit in terms of investment costs per hectare of rice production. The study results indicate that farmers could produce more output per crop and more crops per year. However, a large yield variability was observed amongst the farmers. Among the different water users, the tail-end farmers seem to have lower water accessibility from the dam and the highest yield variability occurred in this group. There are lacks in managerial skills both among the water users and the managers of the scheme. The lack of monitoring and management of the local organisations or the irrigation institutions are constraints for the development of the irrigation sector.

Therefore, the government and local organisations should pay attention to yield stability for the paddy farmers. Farmers' awareness programs, training for efficient utilisation of water resource should be promoted. In addition, policies aiming towards the efficient utilisation of irrigation water, and investments for the maintenance and development of the irrigation infrastructure need to be emphasised to support the irrigation sector in Myanmar. The sample size in this study was rather small, therefore, more research and additional exploration with a larger sample size is needed to confirm the findings.

Furthermore, themes like the impact of irrigation water availability on different land holding categories (small, medium and large farm sizes), and the impact on environment and social aspects would be interesting to consider. Finally, the scope of water management through conducive managerial practices like water management education and training, on effective and efficient utilisation of irrigation water should be carefully studied.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Profitability of apple enterprise among small-holder farmers in South Western Highland Agro-Ecological Zone (SWHAEZ) of Uganda

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The study evaluated the socio-economic viability and factors influencing profitability of apple enterprise under smallholder farming system in Uganda. A sample of 52 apple farming households was randomly selected in the districts of Uganda: Kabale, Kisoro, Kanungu and Rukungiri. Data were collected with the use of structured questionnaires, and analyzed using descriptive statistics, gross margin analysis and multiple regression model. The results showed that apples were planted on small scale with only 6% of land allocated to total apple enterprise in 2011. However, land allocation to apple enterprise is increasing and the enterprise currently covers 20% of farm lands. The dominant varieties among apple farmers are Golden Dorset, 56.1% and Anna, 40.9%. Men constituted 74.5% of the apple farmers, while the mean age of apple farmers was 57 years, with an average experience of over 10 years. Gross margin of apple enterprise in Kabale and Kanungu district had a positive ratio of return on investment of 1.5 and 1.7, respectively. Kisoro and Rukungiri districts had a negative ratio of return on investment of (0.9 and 0.3, respectively). Ordinary least squares (OLS) results indicated that the gender of the respondent, family size, access to credit, influence of birds, type of apple variety, number of apple trees planted, amount of labor used and quantity of inorganic fertilizers applied were significant determinants of net income in apple production. There is need to reduce the labor costs in apple establishment and management, promote strategies that encourage the youth to participate in apple farming. Research has to come up with an effective but affordable remedy against the negative influence of birds in apple production. Farmers need to be linked to financial providers for credit access at low interest rate in order to facilitate routine apple management practices.

Key words: Apple enterprise, smallholder farmers, gross margin, return on investment.

INTRODUCTION

Apple is one of the most popular fruit trees in the World, China is the lead producer followed by European Union (EU) and then United States (FAO, 2016; Wang et al., 2016). Africa contributes 1.43% of the total world apple

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production with South Africa being the major producer (649,218 tonnes). Other apple producing countries in Africa include, Morocco (466,437 tonnes), Egypt (436,931 tonnes), Algeria (364,750 tonnes) and Tunisia (96,000 tonnes) (FAOSTAT, 2013). In Uganda, the apple industry started in 1999 when the Forestry Resources Research Institute (FORRI) and Kawanda Agricultural Research Institute (KARI) initiated trials in the highlands of South-Western Uganda, with the aim of offering farmers an alternative source of income (ICRAF, 2003b). Over the last 7 years, temperate fruit types namely apples, pears, peaches, nectarines, plums, grapes and figs were introduced and evaluated for suitability and productivity in Uganda (Namirembe et al*.,* 2006). At present, apple production lies with small-holder family farmers in the highlands of South-Western Uganda. Two temperate fruits: apples and pears, show potential for adaptability and economic productivity in the zone (Chemining'wa et al*.,* 2005). Although, apple enterprise has become a gainful cash crop for the people of South-Western Uganda, its production in South Western Highlands Agro-ecological Zone (SWHAEZ) and Uganda at large is still at a subsistence level. The enterprise has over the years seen increasing investments in production, purchase and distribution of apple seedlings to farmers across the SWHAEZ in order to foster adoption of apple growing for income generation.

Nonetheless, the country has continued to rely on the importation of the fruits from Kenya and–South-Africa to meet the increasing domestic demand. Uganda imports over 15,000 tons of apples every year (MAAIF, 2012). Given that 1 tonne has 1000 kg, 1 kg has an average of 7 fruits, and each fruit is sold at 700 shillings at wholesale price. Therefore, each year, Uganda roughly loses over 73 billion shillings importing apple fruits without considering juices and other concentrates (MAAIF, 2012). Evidence available indicates that performance of apples has continued to fall both in terms of production and profitability as most farmers continue to abandon their orchards. Attempts to ascertain this general understanding has been limited to factors influencing profitability of the enterprise as more studies have concentrated on production side (Ntakyo et al., 2013). This study assessed the socio-economic viability of apple enterprise, the socio-economic and farm specific factors that influence its profitability in South Western Highlands Agro-ecological Zone of Uganda. The information generated will guide farmers on ways to improve apple productivity and profitability in the study zone.

MATERIALS AND METHODS

Description of the study area

The study was conducted in four districts of Kanungu, Kabale, Kisoro and Rukungiri which lie within the south-western highlands agro-ecological zone (SWHAEZ) of Uganda. The SWHAEZ has predominantly high altitude ranging from 1200 to 2350 m above sea level. The area has agro-climatic conditions that favor a wide range of crops and livestock, as a major source of livelihood for the inhabitants (Wagoire and Kashaija, 2008). The zone receives bimodal rainfall pattern ranging from 1000 to 1500 mm and temperature range is 10 to 30°C. The population density is about 300 persons km^2 with population growth rate of 2.2%, which has continued to exert pressure on land, making it the most limiting resource in agricultural production. Chemining'wa et al. (2005) states that the soils in Kigezi are acidic to slightly acidic loams, reddish brown clay loams, humus loams and yellowish red clay loams with generally a good nutrient supply and with natural fertility and good drainage. The variations in cropping systems are result of the differences in agro-ecological conditions and socio-economic endowments within the districts in the zone (Figure 1).

The findings on the size of land accessible by apple farming households seem to indicate that the farmers involved in the study generally had sizeable land at their disposal. Table 1 shows that the average size of land owned by farmers involved in the study from the four districts was about 34.5 acres. Farmers from Rukungiri and Kabale districts had the highest proportion of land under apple production as compared to their counterparts in Kisoro and Kanungu.

Sample size and selection strategy

The study was carried out on 52 apple farming households that are spread in the districts of Kanungu, Kabale, Kisoro and Rukungiri that form SWHAEZ. The study used multi-stage sampling technique. The first stage was purposive selection of four (4) districts and three (3) sub-counties in each district on the basis of concentration of apple production. The second stage involved purposive selection of atleast two parishes from each of the apple producing sub-counties. The third and final stage involved random selection of at least 35% of apple producers from each parish, making a total of 52 apple farming households for the study. The study used both secondary and primary data in order to meet the study objectives. Qualitative and quantitative primary data was collected through interviews structured to accommodate various categories of respondents. Secondary data was obtained from production, economic and demographic literature from agriculture research stations and national data were consulted to enrich the study. Data collected were subjected to analysis using STATA package version 12.0 to generate descriptive statistics. Input and output data were subjected to gross margin analysis. Multiple regression model was used to determine the factors influencing profitability of apple enterprise.

Analytical technique

Gross margin analysis

Gross margin (GM) was calculated as the gross income of an enterprise minus variable costs. The following mathematical equation illustrated this relationship.

$$GM = P_y Y - \sum_i P_i X_i \qquad (1)$$

Where GM is the gross margin in Uganda shillings per hectare, P_y is the farm gate price of crop product, Y is the quantity of fruits produced per hectare in a given time period, P_i is the farm gate price of a given input used to produce crop output Y and X_i is the cost of the variable input used per hectare.

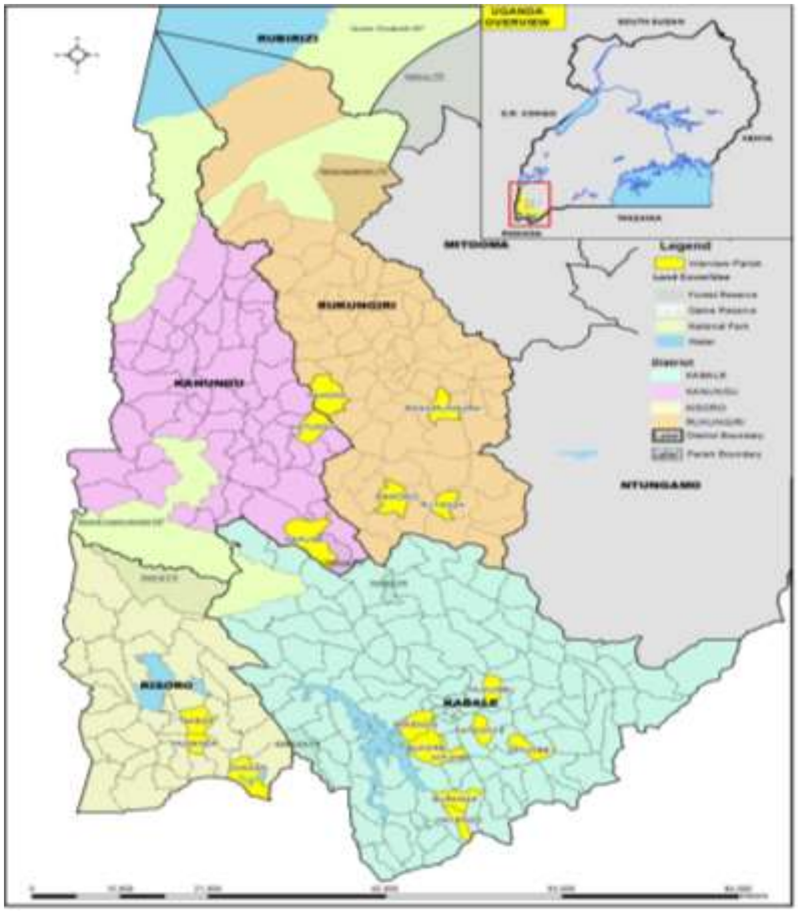

Figure 1. A map of Uganda showing location of the study areas.

Table 1. Household land allocation to apple production in the respective districts.

District	Average land size (acres) accessible by the household	Average land size (acres) under apple production	Land under apple production (%)
Kabale	6.3	1.4	30
Kanungu	7.7	0.9	19
Kisoro	4.0	0.8	17
Rukungiri	16.5	1.6	34
Total	34.5	4.7	100

Source: Field data, 2016.

Variables used

Farm gate prices of the fruits: The prices used for the apples harvested from the farmer's field were prices that the farmer received at the farm gate.

Fruit yields or output: Apple yield was determined on a seasonal basis of the crop. The crop experiences two seasons in the zone, the high production and the low production. The quantities generated for the two seasons were summed to obtain quantities for the whole year.

Costs of inputs: The costs of different inputs used in apple production were determined; that is costs of family labor, costs of hired labor, costs of material inputs such as fertilizers, agro-chemicals. Family labor cost in crop production was calculated as the total value of man-days that the household allocated to the production of a hectare of an enterprise. Total household man-days were calculated as the sum of all labor hours that household members allocated to an enterprise.

Multiple regression model

A multiple regression model was used to determine the factors influencing profitability of apple enterprise in SWHAEZ. Multiple

Table 2. Description of variables used in the model.

Dependent variable	Π_i = **Net Income/Gross margin per farmer**	**Amount in Uganda shillings**	**Expected sign**
Independent variable	**Description**	**Units**	
w_1	Sex of the farmer	Male=1, Female=0	+/-
w_2	Household size of the farmer	Number	+
w_3	Farmers experience	Years	+/-
w_4	Labour	Mandays	+
w_5	Access to Credit	Credit recieved/Landholding by the household	+
w_6	Quantity of inorganic fertilizer used	Kilograms	+
w_7	Farm size	Acres	+
w_8	Nonfarm Income	Uganda shillings	+
w_9	Experieced Birds	Yes =1, No= 0	-
w_{10}	Type of the apple variety	1= Golden Dozet 0= Anna	+/-
w_{11}	Number of trees	Number	+

regression model was selected because it allows for explicit control of factors which simultaneously affect the dependent variable in this case, the gross margin per farmer (Table 4). According to Wooldridge (2004), multiple regression models can accommodate many repressors that may be correlated hence helps to infer causality where simple regression analysis would be misleading. The model was implicitly specified as:

$$\Pi_i = f(W_1, W_2, W_3, W_4, W_5, W_6, W_7, W_8, W_9, W_{10}, W_{11}, \mu_i) \quad (2)$$

Where, Π_i = Net income or gross margin per farmer as the dependent variable; independent variables included; W_1 = sex of the farmer; W_2 = household size; W_3 = farmer's experience; W_4 = labor (Mondays); W_5 = access to credit (ratio of credit received to landholding by the household); WW_6 = quantity of inorganic fertilizer used (kg); W_7 = nonfarm income (Uganda shillings); W_8 = farm size (acres); W_9 = influence of birds (dummy variable); W_{10} = type of apple variety (dummy variable); W_{11} = number of apple trees; μ_i = error term. Refer to Table 2 for description of variables.

The implicit function was linearized and specified in a log linear form (Oluwasola and Ige, 2015) as:

$$Ln\Pi = \beta_0 + \beta_1 W_1 + \beta_2 W_2 + \ldots + \beta_{11} W_{11} + \mu_i \quad (3)$$

According to Gujarati and Porter (2003), the disturbance term is expected to fulfil all the assumptions of the classical regression model except that of homoscedasticity which breaks down when cross sectional data is used. The technique of ordinary least squares (OLS) was used to estimate the multiple regression equation. Selection of the variables used in the regression model (ii), and the a priori expectations were based on the assumptions that in traditional and nearly subsistence farming, enterprises are characterized by resource poor farmers (Table 3). The study adopted a semi-log function other than linear and log-log function to minimize multi-collinearity problem that could arise due the interrelationships among the independent variables. Two diagnostic tests were also utilized such as link test for specification error and heteroscedasticity to guarantee validity and reliability of the results.

RESULTS AND DISCUSSIONS

General description of apple farmers

Information on demographic characteristics of the respondents of interest were: type of apple variety grown, education level, major source of income, sex, age category, membership to a group, land allocation to household enterprises and changes in land size under apples. Table 3 summarizes the findings on these characteristics.

Table 3 indicates that 56.1% of the farmers grow Anna, 40.9% Golden Dorset and 3% Winter Banana. The proportion of farmers that are growing Anna and Golden Dorset varieties as compared to Winter banana is high. These varieties are high yielding, have ability to produce more scions and have been widely popularized (Chemining'wa et al., 2005). The findings indicated that 96% of the respondents had attained some level of formal education and 4% had never attended any formal education. Among those that had attained formal education, 47% had attained part or full primary level education, 33% had attained part or full secondary education and only 16% had been to a tertiary institution.

Table 3. Description of the study respondents.

Variables	Proportion (%)	Means
Type of Apple variety		
Golden Dorset	56.1	
Anna	40.9	
Winter Banana	3.0	
Level of education		
Primary	47.1	
Secondary	33.3	
Tertiary	15.7	
No education	3.9	
Major source of income		
Agriculture	90.2	
Trade	7.8	
Employment	2.0	
Age of the respondent		56.75±12.57
Experience in apple production		10.12±3.58
Willingness to expand orchards		
Yes	66.7	
No	33.3	
Sex of the respondents		
Males	84.6	
Females	15.4	
Land allocation to enterprises		
Apples	5.9	
Other crops	94.1	
Change in land size under apples (hectare) during 2011 and 2015	20.0	

Source: Field data, 2016.

These levels of education of the respondents indicate that almost all the respondents were able to read and write. As expected, 90% of the respondents had agriculture as their major source of income. The other 10% of the respondents regarded non-farm activities as their major source of income. The dominance of agriculture as a major source of income is attributed to the fact that agriculture is the source of livelihood for the people of Uganda (MoFPED, 2014). However, the 10% of the respondents who actually consider non-farm activities as their major source of income confirms the fact that farmers have multiple livelihood sources which may either compete or complement farming.

Our results indicate that the proportion of youth involved in temperate fruit farming in SWHAEZ is generally low. The average age of the farmers was 57 years. Less involvement of the youth in apple growing is probably due to limited ownership of land, preference for white collar jobs and quick paying enterprises. This is in line with the findings by Ahaibwe et al. (2013) in a study on youth engagement in Agriculture in Uganda. This is a potential threat to the current and future production of apples in SWHAEZ. The routine management practices for optimal production of apples require substantial labor which can easily be provided by the young people. It is therefore likely that because most of the farmers are aging, they may not have the needed energy to do all the recommended routine management practices. This implies that they either spend too much on hired labor or they simply ignore some of the practices. A few women (16%) own apple orchards as compared to 94% of the men and yet they contribute the bulk of labor in apple management. This could be due to lack of land ownership in particular (Ellis et al., 2006). A total of 67% of 52

Table 4. Returns and costs comparison from apple investment in Uganda Shillings[1] for the period 2011 to 2015.

Parameter		District			
		Kabale (n=35) '000	Kanungu (n=7) '000	Kisoro (n=6) '000	Rukungiri (n=4) '000
(a) Total Revenue(Ush/hec)		**928,453.61**	**83,002.0**	**1,691.8**	**355,020**
Initial Cost	Land preparation	1,761.9	1,310.0	1,305.0	15,223.0
	Manure collection and application	1,306.1	506.0	334.0	3,330.0
	Planting	1,917.5	414.0	126.0	347.5
(b)	**Total initial cost**	**4,985.4**	**2,230.0**	**1,765.0**	**18,900.5**
Fixed Costs[2]	*Cost of seedling	32,169.6	1,818.0	37,878.0	28,168.0
	*Shovels	58.0	-	44.0	14.0
	*Scissors	507.0	39.0	138.0	113.0
	*Secateurs	30.0	-	-	-
	*Pruning saw	60.0	-	-	-
(c)	**Total Fixed Cost**	**41,233.08**	**1,857**	**38,060**	**28,295**
Variable Cost	Routine labor	152,060.03	25,980.76	18,968.0	35,872.0
	Manure	21,243.0	350.0	5,880.5	379,075.1
	Inorganic fertilizers	3,805.0	200.0	30.0	200.0
	Pesticides	84,522.5	379.5	6,059.0	35,106.0
	Fungicides	58,454.0	179.0	150.0	2.0
	Herbicides	10,070.0	7.5	70.0	1,000.0
	Sisal rolls	289.5	25.0	26.5	16.0
	Pegs	322.5	-	6	502
(d) Total variable cost		330,766.53	27,122	31,190	451,773.10
(e) Total cost at year end		376,985.01	31,208.76	71,015.00	498,968.60
(f) Gross margin (a-e)		551,468.61	51,793.24	-69,323.20	-143,948.60
(g) Gross margin/farmer		15,756.25	7,399.03	-11,554	-35,987.15
(h) Returns on Investment (f/e)		1.463	1.660	-0.976	-0.288

Source: Field Survey, 2016.

farmers were willing to increase on the number of apple trees in their orchards. This could be those farmers that have already benefited from the apple enterprise. However, 33% (a third) noted that they were not willing to increase on the number of apple trees due to limited land, labor intensive, pests and diseases. As evidenced from Table 3, other crops and apples were occupying 94 and 6%, respectively of the total land owned by the farmers. Overall, change of land size over time under apple farming of 20% is still very low. This indicates that the proportion of the land that farmers had allocated to apples and orchard expansion was very low across the surveyed districts. This may be due to long maturity period of apples as compared to other enterprises coupled by lack of knowledge on apple management.

Profitability analysis

Averagely farmers from Kabale district obtained a gross margin of 15,756,250 Uganda shillings and this was realized after 2014 and each farmer from Kanungu district in 2011 was able to realize 7,399,030 Uganda shillings above the costs invested in establishing and routine management of apples (Table 4). This could be due to the proximity of the apple farmers to the research station for ease to access quality apple seedlings and technical backstopping. In Kisoro and Rukungiri districts, apple enterprise was yet to recover about 11,554,000 and 35,987,157 Uganda shillings, respectively of the total costs invested in the establishment and routine management. The returns on investment of apples from Kabale and Kanungu were positive as compared to Kisoro and Rukungiri (Table 4). The results suggest that apple enterprise is economically viable in Kabale and Kanungu.

All financial parameters are expressed in Uganda Shillings (UgX, 000) (1 US dollar ($) = 3320 UgX at time of the study in 2016). The total costs also do not include the costs of some equipment because these could not

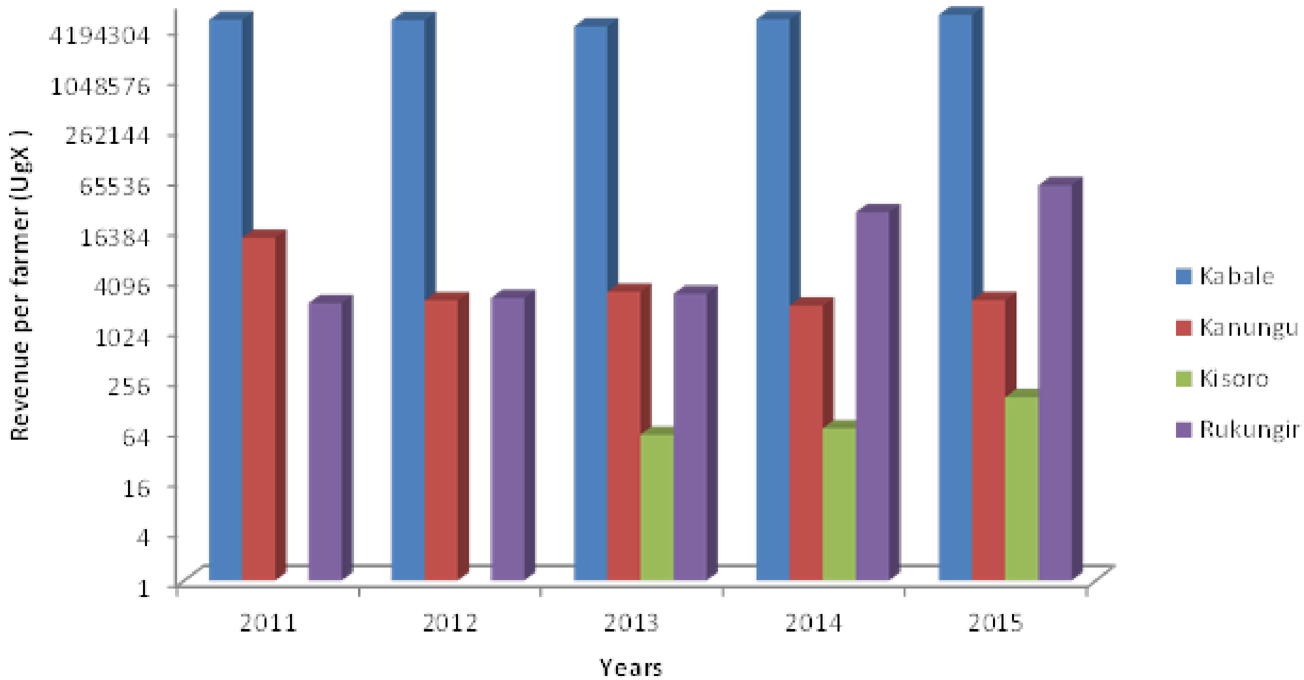

Figure 2. Revenue per farmer across districts.

solely be attributed to apples since farmers reported that they were also using these implements on other enterprises

With regard to cost categories, routine labor, seedling costs, manure, pesticides and land preparation were the major costs in apple production as compared to cost of pegs, sisal rolls, scissors, secateurs, shovels and initial planting (Table 4). Routine labor, manure and pesticides were the variable costs in management of apples and thus these costs are always incurred by the farmers. The initial high seedling costs are attributed to the high cost of seed for generating rootstocks and technical procedures involved in the entire seed production process. This makes it difficult for private individuals with low incomes to invest in generating apple seedlings in order to meet the seedling demand.

The revenue per farmer had an increasing trend for each district from 2011 to 2015 except for the Kabale district where the revenue decreased from 2011 to 2013, then an increase was noticed from 2013 to 2015 (Figure 2). Across the five years, farmers from Kabale district had the highest revenues as compared to Kanungu which had the lowest revenue in question (Figure 2). The high revenues reported by farmers from Kabale district indicate that farmers managed well their apple orchards as compared to farmers from other districts. It is true that Kabale pioneered apple production and they had gained experience and recovered initial investment costs (ICRAF, 2003b). Apple farmers in Kanungu, Kabale and Rukungiri had recovered the initial cost of establishment and routine management in 2011, 2014 and 2015, respectively, while Kisoro had not yet recovered by the time of the study (Figure 2). The slow recovery of the initial costs and routine management costs is attributed to low adoption of apple management practices arising from delay in recruiting extension service providers that were meant to offer the necessary technical advice and support to farmers.

Regression diagnostics

To ensure that the regression model was correctly specified and in line with the assumptions of ordinary least squares (OLS), two diagnostic tests, hetero-scedasticity and specification error were conducted. The regressions results obtained by the OLS method were subjected to heteroscedasticity hettest and specification link test for specification error. The data was checked for heteroscedasticity which is a violation of one of the assumptions of OLS in which the error variance is not constant. Heteroscedasticity is usually a problem in cross sectional data and the data used is no exception. The respective null hypotheses are that, there is no specification error and the residuals are homoskedastic (Table 5). Test for heteroscedasticty was conducted using Breusch-Pagan/Cook-Weisberg. Based on the probability value ($p = 0.0917$) of the Chi-square, the null hypothesis at 10 percent level of significance was rejected, concluding that heteroscedasticity is present. To

Table 5. Detection of heteroscedasticity problem

Breusch-Pagan/Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Vriables: fitted values of input
$Chi^2(1) = 2.85$
$Prob > Chi^2 = 0.0917$

Table 6. Detection of specification error problem.

Inprofit	**Coef.**	**Std. Err.**	**t**	**P>|t|**	**[95% Conf. Interval]**	
_hat	1.31807	1.702944	0.77	0.443	2.107813	4.743952
_hatsq	-0.0101234	0.0540056	-0.19	0.852	-0.1187687	0.98522
_cons	-2.478318	13.42263	-0.18	0.854	-29.48116	24.52452

correct for heterescedasticity problem, robust standard errors were used. The model was also checked for adequacy to ensure it assumed the correct functional form. Results from link test for model specification in Table 6 reveals that in the multiple regression model, the P-values (p= 0.852) of hat squared were not significant at 1% level of significance. This implies that there are no specification errors in the estimating equation hence the model is correctly specified.

The R^2 value of 0.5051 indicates that about 50.51% of the variation in net income or profit realized from apple production in South Western Highland Agro-ecological Zone (SWHAEZ) was determined by the combined effects of the independent variables included in the model (W_1,…, W_{11}), while the remaining 49.49% of the variation was due to other factors not specified in the model such as distance to the market, post-harvest handling and seasonality among others. This implies that the model fits well the data and this is further confirmed by the significance of F-value (p=0.0000). The independent variables conformed to a priori expectations except labor input and farm size (Table 7). Sex of the apple farmer, family size, nonfarm income, access to credit, labor input, type of apple variety, influence of birds, quantity of inorganic fertilizer and number of apple trees were statistically significant at 1 and 5%, respectively.

Sex of the farmer being a dummy for 1 = male and 0 otherwise had the expected sign and statistically significant at 5% level. Based on the a priori expectation, it had been hypothesized that due to differential access to productive resources such as land and access to information, males and male headed households would report higher gross margins than females and female headed households. However, the study findings by Oduol et al. (2017) on avocado value chain in Kenya show that where the chain is well developed and the returns are high as in the export avocado chain, women dominate the production stage while men tend to own the fields, make decisions on sales of fruits of premium quality and control revenues.

The coefficient of family size had a positive coefficient which was statistically significant at 5% level. This implies that an additional one able bodied member in the household would increase net profit by 20% holding other factors constant. Members of the household form part of the labor supply, since apples are labor intensive; increase in the number of household members contributing labor can lead to increase in apple yields. This is in line with the studies done by Chidi et al. (2015) and Okorie et al. (2011), who reported that farmers with increased family size obtained higher yields due to increased family labor supply. Increase in family labor reduces the cost of production as it is not paid for.

Non-farm income from off farm activities had a positive significant influence on the net profits per farmer at 1% level. This implies that a million increase in off-farm income in Uganda shillings of each apple farmer leads to a 0.06% increase in the gross margin by holding other factors constant. This further implies that farmers who participate in non-farm activities create spillover effects on the farm income generated. This is re-affirmed by De Janvry et al. (2005) findings in China who revealed that households who participate in non-farm activities, spillovers raise farm income from 2,383 *yuan* to 7,027 *yuan,* a 195% income gain. They further assert that participation in non-farm activities helps raise total factor productivity in agriculture by relaxing the constraints on agriculture imposed by credit and insurance market failures.

Labor input had a negative significant influence on the net profits per farmer at 1% level (p=0.005) (Table 7). This implies that an additional one unit of labor reduces the net profit of the apple farmer by 0.05% holding other factors constant. This could arise especially when family

Table 7. OLS model results for factors influencing profitability.

Variables	Coef.	Std. Err.	t	P>t
Sex	1.85871**	0.74593	2.49	0.017
Family size	.20039**	0.09318	2.15	0.038
Nonfarm Income	$5.66e^{-08}$***	$2.09e^{-08}$	2.17	0.010
Farmer's experience	0.01631	0.08807	0.19	0.854
Access to credit	0.04699***	0.01536	3.06	0.004
Labor input (Hired and Family)	-0.00043**	0.00018	-2.37	0.023
Type of apple variety	2.9951***	0.66329	4.52	0.000
Farm size	-0.14956	0.09876	-1.51	0.138
Influence of Birds	-1.61591***	0.47987	-3.37	0.002
Quantity of inorganic fertilizers	0.02489***	0.01044	2.39	0.022
Number of apple trees	0.002734***	0.00062	4.43	0.000
Constant	11.66613	1.12121	10.40	0.000
Number of observations	50			
F (11, 38)	67.13			
Prob > F	0.0000			
R-squared	0.5051			
Root MSE	1.566			

*** = Significant at 1% level and **= significant at 5% level.

labor is absent and the apple farmer is forced to rely on hired labor that is expensive given the labor intensive nature of apples management practices.

Type of apple variety, Golden Dorset other than Anna type is associated with an increased net profit. This could be due to fruit sweetness and fruit color that are appealing and attractive to people. According to Andersen and Crocker (2000), it is crispy and juicy, with excellent flavor and has a large market locally than Anna type.

Similarly, an apple farmer that experienced birds in his or her orchards had a reduced net profit as compared to their fellow counter parts that did not experience them at 1% level. Presence of birds in apple orchards can lead to an increased number of apple fruits being wasted, this reduces the yield potential and consequently the net profit. According to Sergio et al. (2006), bird damage-management strategies may have larger market impacts than those employed for other pests, e.g., insects, due to the greater charismatic appeal of birds.

Access to credits had a positive and significant influence on the net profits of apple farmers at 5%. This implies that a farmer that accesses credit from a financial institution is likely to have increased profits holding other factors constant. Better access to the credit will improve the profitability of a great number of farmers, though not necessarily the poorest. In addition, if credit access were improved, it might activate the rural land markets by allowing farmers to rent in or buy the optimal amount of land (Foltz, 2004).

The study findings also revealed that the number of apple trees were associated with a higher profit margin at 1% level of significance. This implies that increase in the number of apple trees by one unit increases the net profit of the apple farmer by 0.2% holding other factors constant. Different farmers have different number of fruit trees planted. Those with many trees get more yields than those with few trees. Farmers with many trees are encouraged with the number and end up putting in a lot of input in the orchard as compared to those with few trees. The more the input one puts in, the more the yield. This however, depends on different management practices a farmer applies in the orchard.

Quantity of inorganic fertilizers was associated with a positive net profit. This implies that a unit increase in the amount of inorganic fertilizer increases net profit of the apple farmer by 2.5% holding other factors constant. Quantity, type and time of application as well as mode of application of inorganic fertilizers in apple orchards determine apple yields and hence net profit. Some farmers apply fertilizers in their orchards, while others do not. Those who apply fertilizers in their apple orchards get more fruit yields than those who do not apply fertilizers at all. However, increased yields come with increased costs of fertilizer which are covered by the credit repayment. Hence, cost of fertilizer largely offsets the increased revenue and thus profit (Matsumoto and Yamano, 2010).

Conclusion and implications

Apple farming requires high initial investment and routine management costs that might not be recovered in the first few years. This then implies that farmers must have alternative sources of income to invest in the establishment and routine management of apples in the first few years. This study has demonstrated that apple enterprises have the potential to generate profits after few years of farming as has been seen in the case of farmers from Kabale and Kanungu districts.

In order to realize better profits, there is need to search for ways of reducing the costs in apple establishment and management. Routine management costs such as routine labor input need to be reduced and hence labor saving techniques need to be emphasized. The study also calls for research to come up with an effective but affordable remedy against birds. This might require assessment of the different methods used by farmers in the region and beyond, so that an effective and environmentally friendly method of dealing with birds can be identified and disseminated among farmers. Additionally, apple farming is a labor intensive crop which as this study has found is dominated by aging farmers. Strategies of attracting and involving the youth into apple farming need to be explored and implemented. Efforts need to be made to ensure continued availability of quality planting materials to farmers at a cost friendly level to enable those who are willing to expand their orchards to do so with ease. Farmers need to be linked to financial providers for access to credit at low interest rate to meet costs related to acquisition of apple seedlings, agro-chemicals, fertilizer and routine labor. Addressing credit market imperfections will enhance the adoption of apple management practices.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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