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Valuation of Cropland Ecosystem Products of Smallholder Farm Households in Hare River Catchment, Southern Ethiopia

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Abstract

The crop production value of nature has to be boldly appreciated in Ethiopia where agriculture is the main livelihood source of most people. However, studies aimed at estimating cropland services were rare in Ethiopia and Hare Catchment. Thus, the objective of this study was to estimate the crop production value of the nature of smallholder farmers of Hare Catchment, Southern Ethiopia. The study applied a quantitative approach and survey design. Data was collected using a questionnaire of 465 households (identified via systematic random sampling) and interviews. Mean, t-test, analysis of variance, and linear regression were used for data analyses. The average net crop production value of nature in the lower, middle and the upper catchment of Hare was US$ 907.3, 455.1, and US$ 512.3 per household/year, respectively. The average production (20.4 quintals) and gross value (US$ 704.8) per/household/year of Hare catchment revealed significant variation among households based on the difference in gender, farm size, labor, and fertilizer used for farming at a 99% confidence level. 78.2% of the crop production variation among farmers was significantly predicted by farm size, labor, seedling, fertilizer, and seed used for farming. The average annual net crop harvest value (US$ 643) of nature was 91.2% of the average revenue (US$ 704.8) from cropland products of Hare. While farm size was the strongest predictor of crop production variation in the lower Hare, labor was the strongest predictor of its variation in the middle and the upper catchment. Thus, government bodies and farmers should take integrated actions to tackle the yield bottle-necks of croplands in Hare Catchment, Southern Ethiopia.

Keywords: *cropland ecosystem, crop harvest, revenue, input cost, net value, Hare catchment*

1. Introduction

Ecosystems could be natural or managed systems, and croplands, basically, are managed ecosystems (Hobbs et al., 2006). An *agro-ecosystem*/*cropland* refers to a collection of farmlands used by people for the production of food crops, fiber, fodder, etc., services (Swinton et al., 2007). *Cropland*, in the Hare River Catchment (HRC), is a land use composed of a set of farm plots used for growing perennial and annual crops such as fruits (e.g., banana, mango, apple), cereals (e.g., barley, wheat, and maize), pulses (e.g., bean and pea), tuber and roots (e.g., potato, cassava, and onion), fibers (e.g., cotton), vegetables (e.g., spinach and cabbage) and others for home consumption (e.g., barley and potato) and cash (e.g., banana, mango, and apple). Agro-ecosystems provide multiple direct and indirect services such as food and non-food products, pollination, biological pest control, landscape beauty, habitat for wildlife, control of water supply, and climate and air quality control (Garbach et al., 2014; Power, 2010; Sthapit and Scherr, 2012; Swinton et al., 2007; Zhang et al., 2007).

Some of the studies on agro-ecosystems focus on the provisioning of products (e.g., food, fiber, biofuel) of croplands (Dovie et al., 2003; Foley et al., 2011; Watson, 2007). Assessing regulatory (carbon sink, micro-climate control) and supportive (habitat provision and soil conservation) cropland services were the targets of some other studies conducted in areas where agroforestry is a dominant practice (Norris et al., 2010; Power, 2010; Sthapit and Scherr, 2012). Still, other studies aimed at addressing one or more of the services to and disservices of agriculture (Garbach et al., 2014; Mahmud et al., 2005; Reeling and Gramig, 2012; Swinton, 2007; Zhang et al., 2007). Disservices are impacts on agriculture and also adverse effects from it (Zhang et al., 2007). Soil management application-based changes in crop yields were also areas of investigation related to croplands in different parts of the world (Garrity, 2004; González-Estrada et al., 2008; Hansen et al., 2007; Posthumus, 2005). Croplands were also evaluated from the viewpoint of improving livelihoods and/or addressing the food insecurity problems of people (Alemayehu et al., 2012; Altieri et al., 2012; Dorosh and Rashid, 2012; Gelaw, 2007; ; IFPRI, 2012; Shackleton et al., 2001 Uncha, 2014). Studies aimed at measuring the net crop harvest value of nature were limited in many Sub-Sahara nations of Africa.

Quantifying the net crop production value of nature requires deducting the costs of inputs incurred for the production of crops from cropland ecosystems (Boyd, 2012; Freeman et al., 2014). Studies targeted to quantify the net crop harvest value of nature were somewhat limited as the valuation experience of scholars is a relatively recent agenda (Costanza et al, 2014). Even, some valuation-based studies made in developing nations failed to account for input costs in measuring the net crop harvest values of nature assuming that the costs of inputs such as wage labor (Dovie et al, 2003; Watson, 2007), improved seeds, and fertilizer (Watson, 2007) are negligible. Since several farmers spend money on the application of fertilizer (Jayne et al., 2003), improved seeds (Spielman et al., 2012), compost, wage labor (Watson, 2007), and lime for crop farming, it is difficult to overlook the cost of such inputs while quantifying the net crop harvest value of nature (Freeman et al., 2014).

Studies aimed at measuring the crop harvest value of nature were limited in Ethiopia. Cost of land degradation-Highlands of Ethiopia (Mahmud et al., 2005), the value of the crop, livestock, and forest products - Bale Mountain Ecosystem (Watson, 2007), valuing pollination service for coffee production (FAO, 2006), measuring irrigation service value through a willingness to pay (WTP) for catchment conservation - Gojam (Tesfaye, 2009), and quantifying the potable water supply services based on WTP for forest conservation–Wondo-Genet (Anteneh, 2014) were among the limited valuation-related studies conducted in Ethiopia. Different studies were also conducted within and nearby HRC where this study is conducted (Assefa & Bork, 2016; Gelaw, 2007; Kebede, 2012). None of these studies attempted to quantify the crop production value of nature in the area. Though crop harvest is a function of various farm inputs (e.g., labor, fertilizer, farmland, and others) (Watson, 2007; Spielman et al., 2012), studies aimed at evaluating the impact of these variables on annual production are also limited in HRC.Measuring the net crop harvest value of nature is useful for financial evidence-based appreciation of nature, persuading farmers about the management problems of croplands, and mobilizing them for interventions on croplands (Boyd, 2012).

This study was targeted to (1) Measure the production and net crop harvest value of nature for smallholder farm-HH of HRC. (2) Analyze the impact of farm inputs on the crop harvest variation among farm-HH. (3) Compare the amount of crop harvest value of farm-HH of the Lower Catchment (LC), Middle Catchment (MC), and the Upper Catchment (UC) of Hare in Southern Ethiopia.

2. Study Area and Research Methods

2.1 Description of Study Area

***Location and topography*:** HRC is located between 6002’13’’– 6017’55’’ N and 37027’09’’ – 37037’51’’ E (Figure 1). It is largely part of Gamo Highland, and its smaller part is in the Ethiopian Rift Valley. It has an area of 23,432.7 ha. Much of HRC is a rugged and undulating landscape where its altitude is 1170 – 3484 m above sea level. Based on FAO (2007) gradient classes, 55.8 % (13,075.5ha) of HRC is strongly sloping to moderately steep (5 - 15˚) and 12.3 % (2,882.2ha) is steep (15 - 30˚) to very steep (over 30˚); but 31.9 % (7,475ha) is gentle and more of plain (below 5˚) (Appendix: Table 9). It is drained by the Hare River and its tributaries (Figure 1).

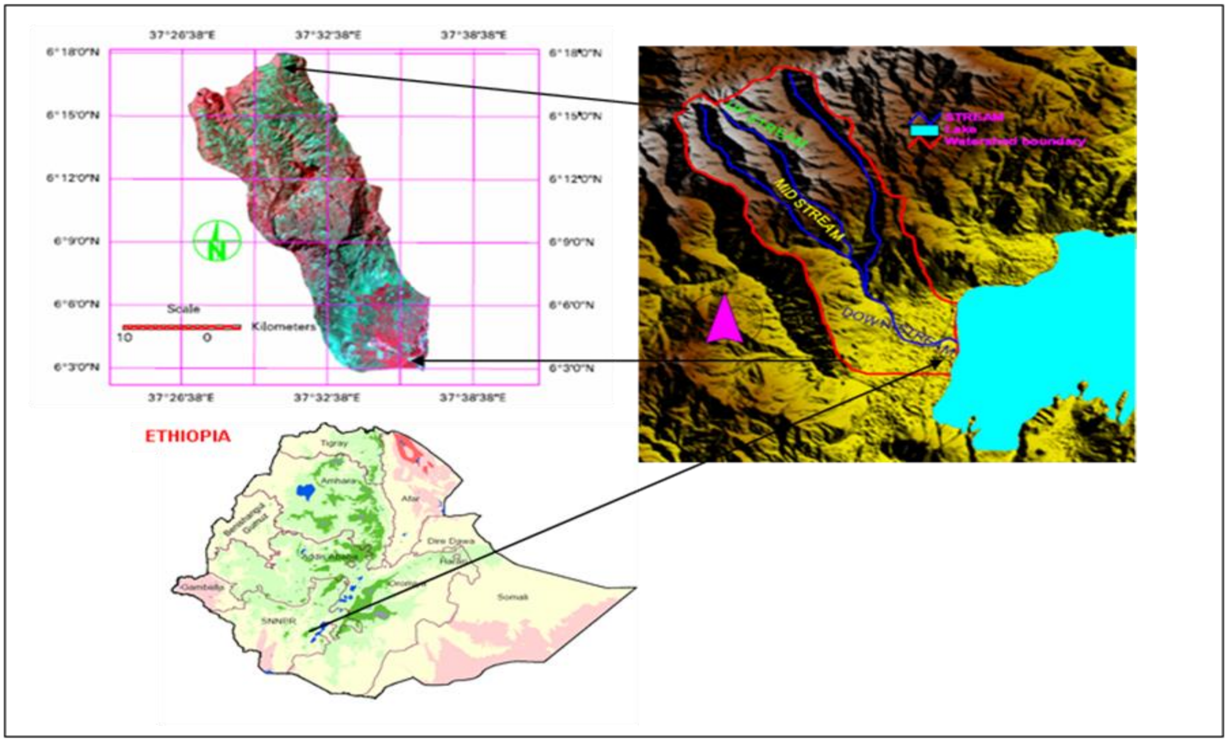

Figure 1: Location of Hare River Catchment (HRC), Southern Ethiopia (**Source**: Kebede, 2012)

***Climate*:** HRC experiences a mean annual temperature of 16.7 0C in the Middle and Upper Catchment (MUC) and 24 0C in its LC (NMA, 2019). While March is the hottest month in the LC (26 0C) and the MUC (18.6 0C), July is the coldest month in the LC (23 0C) and the MUC (14.9 0C) (Table 1). High cloud cover made July the coldest month (14.9 0C) in the MUC of Hare. The mean total annual rainfall of HRC (1982 – 2018) varies from 870.9 mm in the LC to 1406.5 mm in the MUC (Table 1). HRC receives rainfall in March-May/June (the main rainy season) and August/September-November (the second rainy season) (Table 1).

Table 1. Mean Temperature (T) (1987 - 2018) and Rainfall (RF) (1982 - 2018) in the LC and the MUC of Hare

Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
LC: T (^{0}C)	24.2	25.2	26.0	24.8	23.7	23.2	23.0	23.6	24.3	23.7	23.1	23.1	24.0
LC: RF (mm)	26.6	31.1	58.1	153.7	151.1	61.5	41.6	47.0	85.8	115.0	64.8	34.6	870.9
MUC: T (^{0}C)	17.9	18.3	18.6	17.2	17.1	15.6	14.9	15.0	16.0	16.3	16.9	17.0	16.7
MUC: RF_mm	36.6	27.5	100..4	229.6	216.9	102.6	76.0	139.1	169.3	157.8	107.3	43.4	1406.5

Source: The Author's Computation Using Data of NMA (2019). Note: MUC = Middle and Upper Catchment

Soil: fluvisols and leptosols are found in the greater part of HRC (Kebede, 2012). Calcaric fluvisols, being sandy loam, loam or sandy clay to loam, deep, neutral to alkaline, highly fertile, and productive, dominate the plain LC (Gelaw, 2007; Kebede, 2012). The shallow and less fertile leptosols are features of the rugged landscapes in the MC and UC; cambisols, having good fertility, are found in the northwestern part of the LC where colluvial deposit is common (Kebede, 2012). Acidity, leaching, and erosion are the yield threats of soils (leptosols, cambisols, and acrisols) in the MC and UC of Hare (Assefa, 2001; Kebede, 2012).

Agro-ecology and crop farming**:** agro-ecological zones of HRC vary from *Kola* (tropical) to *Wurch* (alpine - along Surra-Gugie Ridge) (Hurni, 1998). Crop farming is a vital livelihood basis even if livestock rearing is also practiced by people of the area. The LC, with 1170 – 1500 m elevation and mean annual temperature of 24 0C (NMA, 2019), experiences *Kola* (tropical) agroecology (24 %) where agroforestry, tuber and root crops, and cereals are grown by farmers. The MC, being 1500 – 2300 m high, has *Woina-Dega* (sub-tropical) agro-ecology (23.7 %) (Appendix: Table 7). The UC (48.3 %) reflects *Dega* (temperate) agroecology since its altitude is 2300 – 3200 m; and HRC exhibits *Wurch* (alpine) condition (4 %) where its elevation is 3200 – 3484 m (Appendix: Table 7). Cereals, pulses, tuber and root crops, and fruits are grown by HH of the MC and the UC where *enset* (false-banana) is a key staple food crop. Crop farming in HRC is practiced in *Belg* or Spring (March to May/June) and *Meher* or Autumn (August/September to November) season (Table 1; Abera, 2014).

***Population*:** HRC was characterized by scattered settlements since it is predominantly inhabited by rural people whose principal source of livelihood means originates from agriculture. The Catchment was inhabited by 64,671 people, where females constitute 50.6 % (32,724) and males account 49.4 % (31,947) (CSA, 2015). Well over three-fifth (63.2 % or 40,900) of the population lives in the MC and UC, and slightly over one-third (36.8% or 23,771) lives in the LC (CSA, 2018).

2.2 Research Methods

2.2.1 Research Design and Methods of Data Collection

The quantitative approach was dominantly applied as the study aimed solely at estimating the crop harvest values of nature. This approach enables the researcher to draw statistical-based inferences about the study population based on the analysis of data acquired using a representative sample (Creswell, 2009). A survey design was used as it allows the acquisition of broad data about several issues within a defined and relatively short period (Creswell, 2009). Primary data was gathered using a questionnaire and interviews. The questionnaire, with more close-ended questions, was used to collect data about the crops grown, crop harvest and their prices, farm inputs and their costs, threats on farming, etc., for the 2018/19 harvest season. The interview was used to collect data about the threats to crop farming and yield, cropland management conditions, and prices of crops. Secondary data (e.g., climate and empirical literature) was collected from books, journals, proceedings, reports, and others.

2.2.2 Sampling Techniques

HRC was classified into LC, MC, and UC using changes in elevation, vegetation, and crops are grown using stratified sampling. *Kebele* Peasant Administrations (KPA) were selected using simple random and purposive sampling.

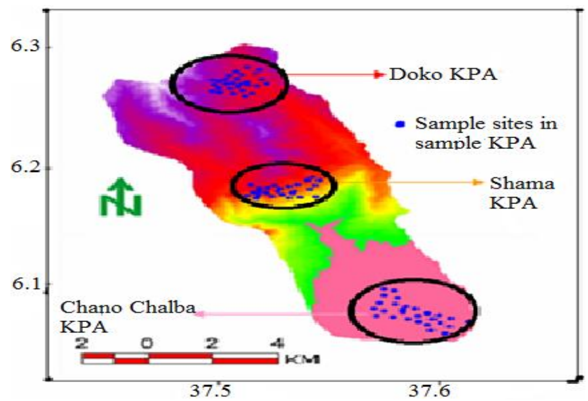

Figure 2: Sample KPA Used for Household Data Collection from HRC **(Source:** Adapted from Kebede, 2012)

One KPA (Chano-Chalba) was selected from the LC using a simple random sampling technique since all the KPAsare fully located within Arba-Minch-Zuria *Woreda* plus the LC when sample KPAs like Shama (from MC) and Doko (from UC) were chosen using purposive sampling technique (Fig 2). The criteria of purposive sampling were whether a sample KPA is fully situated in one *Woreda* (i.e., Chencha) and whether its admin boundary lies fully in the MC or UC. In Ethiopia, *kebele* is the smallest admin unit when *woreda* is a larger one consisting of many *kebeles*.

The sample size of this study was determined using (Kothari, 2004) for inferences at least at 95 % confidence level, where the minimum sample size became 373 HH from 12,202 total HH of HRC (DANRP, 2018); where: ‘n’ is the sample size, ‘N’ is population and ‘e’ is the standard error (0.05), ‘z’ is the standard value of desired confidence level that is 95 % (1.96), ‘p’ is desired sample proportion (0.5) and ‘q’ = 1 – p (i.e., 0.5). But 465 sample HH heads were taken for questionnaire administration to optimize the return probability of the copies of the questionnaire. The 465 sample HH heads were selected using systematic sampling technique, and they account for 19.3 % of the total HH (2406) of the sample KPA, such as Chalba (892 HH), Shama (705 HH), and Doko (809 HH) (DANRP, 2018). Proportionally, about 37.4 % (174), 28.8 % (134) and 33.8 % (157) sample HH were taken from the LC (i.e., Chalba), the MC (i.e., Shama) and the UC (i.e., Doko), respectively. The interview was conducted with three Development Agents, three KPA Admins, and six farmers who were selected using purposive sampling.

2.2.3 Techniques of Data Analysis

Data were analyzed using mean, correlation, t-test, analysis of variance, and multiple linear regressions. The market value was used to measure crop products and input costs. Production in quintals (q), revenue, and net crop harvest value of nature were estimated using the formulas given below (Penzer, 2011): ***(1) Total production (y): y = ∑(sh*ay)***, where: '***sh***' is sample HH who cultivated crops '1' to 'n' and '***ay***' is the average harvest of each crop. ***(2) Crop revenue (cr) (ETB/US$): cr = ∑(sh*ay*ap) = ∑(y*ap***), where: '***sh***' is sample HH who cultivates crops '1' to 'n', '***ay***' is the average harvest of each types of crop, and '***ap***' is the average price of each crop. ***(3) Farm input cost (fic): fic*** = ***∑(sh*ai*ac),*** where: '***sh***' is sample HH who uses inputs '1' to 'n,' '***ai***' is the average of each farm-input '1' to 'n' and '***ac***' is average cost of each input '1' to 'n'. ***(4)* Net value *(NV)*: *'NV' = ∑(cr - fic)***, where: ***cr = ∑(sh*ay*ap***) (from Eq. 2) and '***fic***' = ***∑(sh*ai*ac***) (from Eq. 3). Costs were considered for inputs like wage labor, fertilizer, rental water pump motor, seedlings (banana, mango, and apple) and seeds (maize, onion, barley, wheat, bean, pea, and potato). The average exchange rate of 2018/19 was used to convert the monetary value from ETB to US$, which was US$ 1 ÷ ETB 28.5 (0.0351) (NBE, 2019).

Multiple linear regression analysis was run using SPSS for evaluating the impact of HH-related independent variables (farm inputs) on the dependent variable (crop produce/harvest) using: y = a + b1x1 + b2x2 + b3x3 + b4x4 + b5x5 + b6x6+ u (Kothari, 2004; Gujarati, 2004; Penzer, 2011); where: 'y' is observed crop produce/harvest, 'a' is constant, x1 is farm size, x2 is labor, x3, is pair of oxen power, x4 is fertilizer, x5 is seedlings, x6 is seeds; and b1 , b2, b3, b4, b5, and b6 are coefficients of x1, x2, x3, x4, x5 and x6, and 'u' is residual [is observed (y) minus (-) predicted (Ŷ) cropland produce, that is, y – Ŷ]. But oxen power was accounted for only in the LC since oxen are not used for farming in the MC and UC due to high fragmentation of farm plots and small farm size. This analysis was made to determine the proportion of 'production' that is predicted (explained) by the independent variables. Standardized beta coefficients were applied to identify the predictor/s with stronger and weaker influences on the dependent variable (crop produce). Analyses results of the different sets of data were organized and interpreted. Discussions were also conducted about the results with the support of the findings of empirical studies on related issues and based on the evidence obtained through interviews.

2.2.4 Assumptions:

Statistical and economic assumptions were set about the models/tools and evidence used for analysis in this study (Gujarati, 2004; Kothari, 2004; Moore et al., 2009; Penzer, 2011):

***(I) Statistical Assumptions*:** (1) In the regression analysis, the Independent Variables (IV) (farm inputs) were assumed to have a linear (cause-effect) association with the Dependent Variable (DV) (crop produce); that is, y = a + b1x1 + b2x2 + b3x3 … + bnxn; where: 'y' is the DV; x1, x2, x3 and x n are IV; b1, b2, b3 and b n are coefficients of x1, x2, x3 and xn, respectively (Gujarati, 2004). (2) All variables in the sample are assumed to have more or less uniform population distribution; hence, the sample is an unbiased estimator of the population mean (Penzer, 2011). (3) Since the study population is assumed to be normally distributed, the distribution of the sample mean became normal (i.e. mean = mode) at a 95% credible interval based on the Bayesian one-sample test (Lin, 2013).

***(II) Economic Assumptions*:** assumptions were set for the following variables: 1) Seedlings planted in 2018/19 were assumed to be surrogate inputs of the produce obtained from perennial crops (banana, mango, *enset*, and apple) by smallholder farmers of HRC in the same year. 2) Prices at local markets (within and nearby HRC) during 2018/19, were assumed to have been appropriate for measuring values of crop products in the area; thus, evidence (price/unit product) was acquired from sample HH and based on existing market values of products, then. 3) 'Farm size' was used as one predictor in the regression analysis assuming that 100 % of the farmland of each HH was utilized for the 2018/19 crop harvest in HRC. 4) Labor cost was assumed to be variable (instead of fixed); thus, the mean wage of daily laborers (ETB/day) in HRC was assumed to be the minimum labor cost, and hence, it was used for computing the net economic value of the crop products under study.

3. Results and Discussion

3.1 Results

3.1.1 Products (Harvests) and Revenue (Income) from Croplands of HRC

HRC (especially the LC) is endowed with diverse species of crops since it reflects a tropical climate. The production and revenue/income from croplands of the LC, MC, and the UC of HRC (for 2018/19) are organized in Table 2a, Table 2b, and Table 2c. The crop products in the LC of Hare are derived from agro-forestry (banana, mango, avocado, and papaya), cereals (maize and *teff*), pulses (haricot bean), tuber and root crops (cassava, sweet potato, and onion), vegetables (cabbage and moringa), other fruits (tomato and pepper) and fibers (cotton). Over half (55.1 %) of the total crop harvest was obtained from bananas, followed by mango (20.4 %), onion (7.8 %), and maize (7.2 %) (see Table 2a). The average crop harvest (35.4 quintals/HH/year) of the LC was relatively high due to better farm size (0.60 ha/HH) (Appendix: Table 5) and fertile soils (Gelaw, 2007; Kebede, 2012).

Table 2a: Average/Mean (*ay*) and Total Crop Production (*y*), Average Price (*ap*), and Estimated Crop Revenue (*cr*) of the Farm-HH of the LC in 2018/19

N0	Crops	Farm-HH		Production (*Quintal*/Year)			a_p/*quintal*		Revenue (US$)	
		s_h	%	Mean (a_y)	$y = s_h * a_y$	%	ETB	US$	$c_r = y * a_p$	%
1	Banana	157	90.2	21.60	3,391.20	55.1	769	26.9919	91,534.9	53.6
2	Mango	116	66.7	10.80	1,252.80	20.4	738	25.9038	32,452.3	19.0
3	Tomato	59	33.9	4.85	286.15	4.7	868	30.4668	8,718.1	5.1
4	Avocado	51	29.3	1.00	51.00	0.8	894	31.3794	1,600.3	0.9
5	Papaya	28	16.1	1.41	39.48	0.6	708	24.8508	981.1	0.6
6	Maize	155	89.1	2.87	444.85	7.2	810	28.4310	12,647.5	7.4
7	Haricot bean	54	31.0	0.51	27.54	0.5	938	32.9238	906.7	0.5
8	Cassava	53	30.5	0.62	32.86	0.5	800	28.0800	922.7	0.6
9	Sweet p.	68	39.1	0.71	48.28	0.8	851	29.8701	1,442.1	0.8
10	Onion	46	26.4	10.49	482.54	7.8	902	31.6602	15,277.3	8.9
11	Pepper	26	14.9	1.05	27.30	0.5	800	28.0800	766.6	0.5
12	*Teff*	33	19.0	0.38	12.54	0.2	2564	89.9964	1,128.6	0.7
13	Cabbage	10	5.8	3.20	32.00	0.5	768	26.9568	862.6	0.5
14	Cotton	45	25.9	0.55	24.75	0.4	1850	64.9350	1,607.1	0.9
	Total	**174**	**-**	**-**	**6,153.3**	**100.0**	**-**	**-**	**170,847.9**	**100.0**

Source: Own Calculation upon HH Data (2019). Note: Data are from multiple response options

The estimated crop harvest value of nature by HH of the LC was US$ 981.9/HH/year (170,847.9÷174). Average product variation among HH of the LC was significant, based on the differences in farm size, HH-size, fertilizer, and labor used for farming at a 99% confidence level (all sig values were 0.000), but gender difference-based production variation was not significant (Appendix: Tables 1b). Crop harvest was larger for HH with more HH-size, and those who used more farm-size, fertilizer, and labor than the farm HH who used a smaller amount of these inputs. Crop harvest in the LC is threatened by a fruit disease/pest, rainfall scarcity, spoiling of fruits due to high mean annual (24 0C) temperature (NMA, 2019), and lack of preserving facilities for fruits.

A 38 years-old farmer indicated that farmers sell fruits at a cheaper price, feed for livestock, and/or dump the products due to spoiling especially during the high production season. Another informant (52 years old farmer) said that the impact of the strange disease/pest (described, by a 34 years old Development Agent, as fungus) is greater on mango fruit.

The diversity of crops decreases from the Kola (tropical) agro-ecology of the LC to the hilly Woina-Dega (sub-tropical) MC and Dega (temperate) UC of Hare (Table 2b and Table 2c). Over three-fourths (75.6 %) of the total crop harvest of the MC were derived from potato (41.1 %), barley (19.9 %) and enset (14.6 %) cultivation in 2018/19. The contribution of apple (10.4 %), wheat (8.8 %), and other crops (bean, pea, and garlic) were limited (Table 2b). The average produce of the MC was estimated at 10.3 (1,380.3÷134) quintal/HH/year and the value of crop harvest was US$ 505.2 (US$ 67,698.4÷134 HH) per/HH in 2018/19 (Table 2b). Over four-fifth (82.9 %) of the estimated value of the crop produce was accounted by enset (23.5 %), apple (22.4 %), potato (19 %) and barley (18 %) harvest (Table 2b). Amount of crop production exhibited significant variation among HH of the MC based on variation in gender, HH-size, farm-size, fertilizer, and labor used for cultivation at 99 % confidence level, where sig-values of all were less than 0.01 (Appendix: Table 1c]. That is, the average harvest of male-headed HH was significantly larger than that of female-headed ones; farmers having larger HH-size and farm-size, and those who used more fertilizer and labor inputs produced larger average crop harvest (quintal/HH).

Table 2b: Average/Mean (a_y) and Total Crop Production (y), Average Price (a_p) and Estimated Crop Revenue (c_r) of the Farm-HH of the MC in 2018/19

N0	Crops	Farm-HH		Production (*Quintal*/Year)			a_p/*quintal*		Revenue (US$)	
		s_h	%	a_y	$y = s_h * a_y$	%	ETB	US$	$c_r = y * a_p$	%
1	Barley	131	97.8	2.1	275.1	19.9	1,263	44.3313	12,195.5	18.0
2	Wheat	87	64.9	1.4	121.8	8.8	1,657	58.1607	7,084.0	10.5
3	Apple	41	30.6	3.5	143.5	10.4	3,005	105.4755	15,135.7	22.4
4	Bean	52	38.8	0.8	41.6	3.0	1,515	53.1765	2,212.1	3.3
5	Pea	41	30.6	0.6	24.6	1.8	2,137	75.0087	1,845.2	2.7
6	Potato	132	98.5	4.3	567.6	41.1	646	22.6746	12,870.1	19.0
7	*Enset*	126	94.0	1.6	201.6	14.6	2,250	78.9750	15,921.4	23.5
8	Garlic	9	6.7	0.5	4.5	0.3	2,750	96.5250	434.4	0.6
	Total	**134**	**100**	**-**	**1,380.3**	**100**	-	-	**67,698.4**	**100.0**

Source: Own Computation Based on HH Data (2019/20). Note: Data are from multiple response options

Again (in the UC), potato (52.2 %), barley (17.1 %), enset (9.8 %), and apple (8.7 %) harvest accounted for about 87.8 % of the total production in 2018/19. Compared to the proportion (%) in the total harvest, the share of apple (21.1 %) and enset (17.7 %) products in the estimated value was somewhat larger even though the share (%) of each was less than that of potato (27.1 %). The average production of the UC was 13 (2,045.5÷157 HH) quintal/HH/year, and the mean crop harvest value was US$ 567.9 (89,166.4÷157 HH) per/HH (Table 2c). The average harvest revealed significant variation among HH of the UC based on variation in gender, HH-size, farm-size, fertilizer, and labor used for production at a 99 % confidence level, where sig-values of all these were less than 0.01 (Appendix: Table 1d). Generally, in 2018/19, about 64.3 % of the total crop harvest of HRC was generated from the LC, followed by that of the UC (21.3 %) and the MC (14.4 %) (Figure 4). The 41-year-old and 33-year-old Development Agents stated that steepness of farmland, runoff erosion, soil acidity, farmers' resistance to the use of chemical fertilizer, over-cultivation (i.e., the use of land for growing the same crops for a long), shallow and poor soil fertility (Kebede, 2012) are among the main threats of farming in the MC and the UC.

Table 2c: Average/Mean (a_y) and Total Crop Production (y), Average Price (a_p) and Estimated Crop Revenue (c_r) of the Farm-HH of the UC in 2018/19

N0	Crops	Farm-HH		Production (*Quintal*/Year)			a_p/*quintal*		Revenue (US$)	
		s_h	%	Mean (a_y)	$y = s_h * a_y$	%	ETB	US$	$c_r = y * a_p$	%
1	Barley	146	93.0	2.4	350.4	17.1	1,263	44.3313	15,533.7	17.4
2	Wheat	110	70.1	1.3	143.0	7.0	1,657	58.1607	8,317.0	9.3
3	Apple	51	32.5	3.5	178.5	8.7	3,005	105.4755	18,827.4	21.1
4	Bean	83	52.9	0.9	74.7	3.6	1,515	53.1765	3,972.3	4.5
5	Pea	60	38.2	0.4	24.0	1.2	2,137	75.0087	1,800.2	2.0
6	Potato	157	100.0	6.8	1,067.6	52.2	646	22.6746	24,207.4	27.1
7	*Enset*	133	84.7	1.5	199.5	9.8	2,250	78.9750	15,755.5	17.7
8	Garlic	13	8.3	0.6	7.8	0.4	2,750	96.5250	752.9	0.8
	Total	**157**	**100**	**-**	**2,045.5**	**100**	**-**	**-**	**89,166.4**	**100.0**

Source: The Authors' Computation Based on Field Survey Data (2019)

The average crop production in the overall HRC was estimated at 20.6 quintals/HH in 2018/19, and the production (per/HH/) ranged from 2 quintals of the MC and the UC to 119 quintals of the LC (Appendix: Table 5). The variation in the average crop harvest between HH of the LC vs., the MC and the LC vs., the UC was significant at a 99 % CL; this (with a sig-value of 0.014) was also true for the MC vs., the UC only at 95 % CL (Appendix: Tables 4a, 4b & 4c). That is, the average crop harvest by farm-HH of the LC (35.4 quintals) was significantly higher than that of the UC (13 quintals) and the MC (10.3 quintals) (Appendix: Table 5).

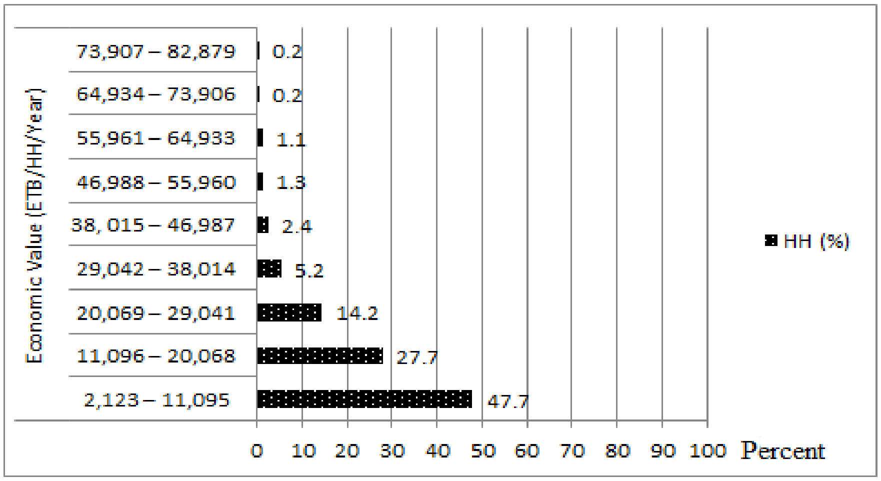

Figure 3: Distribution (%) of Farm-HH of HRC Based on Estimated Revenue (ETB) of Crop Harvest in 2018/19 (**Source**: Own Design via Excel upon HH Survey Data, 2020)

The average crop harvest also revealed significant variation among farm-HH of HRC based on disparities in gender, HH size, farm size, labor, fertilizer, and seedling amount used for the 2018/19 production, where all sig-values of these variables were less than 0.01 (0.000) (Appendix: Table 1e). The estimated value of crop production for 47.7 % of the HH of HRC was about ETB 2,123 – 11,095 in 2018/19; and it was ETB 11,096 – 20,068 and 20,069 – 29,041 for 27.7 % and 14.2 % of them, respectively (Figure 3). The households whose estimated value of crop harvest was ETB 29,042 – 82,879 accounted for only 10.4 % of the whole HRC. In other words, the earnings from crop harvest for nearly one-fourth (24.6 %) of the HH of HRC was about ETB 20,069 – 82,879, and it was less than ETB 20,069 for 75.4 % of them annually (Figure 3). The estimated revenue from crop harvest of HRC was US$ 704.8 (i.e., US$ 327,712.7÷465 HH) per/HH in 2018/19 (Appendix: Table 5).

3.1.2. The Cost and Net Economic Value (NV) of Production/Harvest from Croplands of HRC

Measuring the NV of nature through crop harvest requires deducting the cost of inputs used for farming (Freeman et al., 2014). The farmers of HRC had spent money on wage labor, fertilizer, Water Pump Motor (WPM) for irrigation, and improved seeds (of maize, onion, barley, wheat, bean, pea, and potato) and seedlings (of banana, mango, and apple) for the 2018/19 crop harvest (Appendix: Tables 6a, 6b, 6c, 6d & Table 6e).

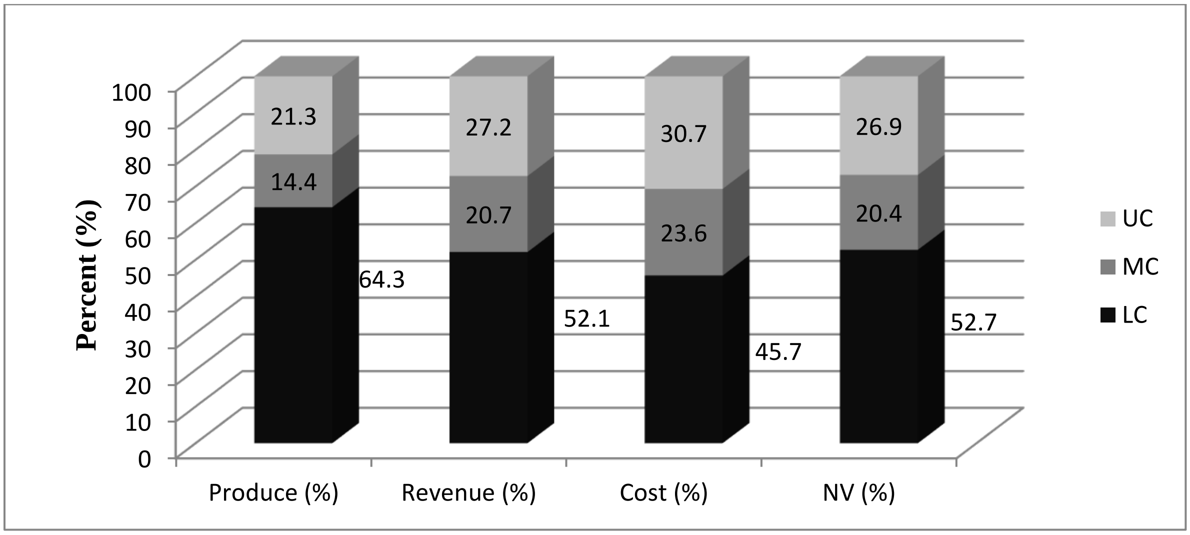

Figure 4: The Share (%) of the LC, MC and the UC in the Production, Revenue, Input Cost and NV of Crop Harvest of HRC in 2018/19 (**Source:** Own Design via Excel, 2020)

The smallholder farmers' tendency to use wage labor was limited in the MC and UC due to low income even if farming in these sub-catchments requires higher labor. About 79.5 % of the total input expense for the 2018/19 harvest in HRC was spent on wage labor (42 %) and fertilizer (37.5 %) when the cost of the other inputs was low (Appendix: Table 6e). The level of farm input expense of the LC was significantly higher (45.7 %) than that of the UC (30.7 %) and the MC (23.6 %). The NV of nature through crop harvest of the LC was the highest (52.7 %), but it was smaller in the UC (26.9 %) and the MC (20.7 %) (Figure 4). The average NV (US$/HH/year) of nature through crop harvest was US$ 907.3 in the LC, US$ 512.3 in the UC, US$ 455.1 in the MC, and US$ 643.6 in the overall HRC (Appendix: Table 5). The net crop harvest value (US$ 643.6) of nature was about 91.3% of the overall average revenue (US$ 704.8) from crop products of HRC. The variation of average NV of crop harvest among HH of HRC was significantly based on differences in gender, HH-size, farm size, labor, and fertilizer used at a 99 % confidence level (Appendix: Table 1f). That is, the average earning of male-headed HH was significantly higher than that of females; it was also significantly higher for HH having more HH size and farm size, and for those who used more amount of labor and fertilizer for the 2018/19 crop harvest. Location and agro-ecology difference-based variation of average income from crop harvest between the LC vs., the MC (with t-statistic of 8.31 and sig-value of 0.000) and the LC vs., the UC (with t-statistic of 7.01 and sig-value of 0.000) was significant even if it was not true of the MC vs., the UC at 99 % confidence level (Appendix: Tables 4a, Table 4b & Table 4c). This means the revenue (earning) from crop harvest of the LC was significantly higher than that of the MC and the UC.

3.1.3 Impact of Farm Inputs (Predictors) on Crop Produce/Harvest in HRC

Understanding the impacts of farm inputs on crop harvest requires conducting regression analysis. Collinearity diagnosis was done to check whether the correlation between predictors and their Variance Inflation Factor (VIF) inflates the variation explained on the DV. VIF is a measure of exaggeration of the DV caused by predictors having a very strong correlation. If the correlation (r) between regresses exceeds 0.8, and their VIF is > 10, the variation predicted on the DV is exaggerated, making it difficult to run regression analysis (Gujarati, 2004). But the correlation coefficients (r) of all predictors used in this study were < 0.8 (Appendix: Table 1a), and the VIF of all the regresses was also < 10 (See Table 3b, Table 3c, Table 3d & Table 3e).

Table 3a: Model Summary of the Regression Analyses (Significance at 99 % Confidence Level)

N0	Category	R	R^2	Adjusted R^2	SE of Estimate
I	Lower Catchment (LC)	0.905[a]	0.820	0.806	1.79
II	Middle Catchment (MC)	0.909a	0.826	0.810	0.94
III	Upper Catchment (UC)	0.980a	0.960	0.956	0.81
III	Overall HRC	0.884[a]	0.782	0.777	1.75

a) Predictors: (Constant), Seed, Seedling, Fertilizer, Oxen power (in LC only), Labor, Farm size; **b) DV:** Crop Produce/Harvest (Quintal/HH/Year)**. (Source:** Own Analysis Using SPSS-version 20, 2020).

It was found that 82 % of the variation in average crop harvest among HH of the LC was significantly predicted by variation in farm size, oxen-power, labor, fertilizer, seedlings, and seeds used for production at a 99 % Confidence Level (CL) (Table 3a). A huge share (%) of the production in the MC (82.6 %) and the UC (96 %) was also significantly predicted by the same farm inputs used for estimation (except oxen-power) at 99 % CL (Table 3a). Here, the seedling is an input used for growing banana, mango, papaya, etc., perennials in the LC, and for enset and apple farming in the MC and UC. Variations in the number of seed, seedlings, fertilizer, labor, and farm size used for the 2018/19 production have also significantly predicted 78.2 % of the variations in the average crop harvest among HH of HRC (Table 3a). ANOVA (0.000b) of the regression analysis also showed that the prediction of the DV (crop harvest) based on the five predictors was significant at 99% CL.

Table 3b: Beta Coefficients[a] and Collinearity Statistics of Predictors of Crop Harvest in the LC

N0	Predictor Variables	Beta Coefficients			Statistics		Collinearity Statistics	
		Unstd.	Std. E	Std	T	Sig	Tolerance	VIF
1	(Constant)	-	0.791	-	-	0.000	-	-
2	Farm size (ha)	0.730	0.149	0.351	4.89	0.000	0.450	2.223
3	Oxen (pair/HH/Y)	0.232	0.177	0.091	1.30	0.194	0.479	2.089
4	Labor (#/HH/Year)	0.464	0.117	0.292	3.96	0.000	0.427	2.343
5	Fertilizer	0.461	0.149	0.193	3.08	0.003	0.588	1.699
6	Seedlings (#/HH/Y)	0.123	0.033	0.198	3.71	0.000	0.813	1.230
7	Seed (kg/HH/Y)	0.032	0.045	0.041	0.72	0.472	0.722	1.385

a. DV: Produce, Q/HH/Year. (**Source**: Own Analysis Using SPSS, 2020).(**Note**: Unstd. = Unstandardized; Std. E = Standard Error; Std. = Standardized; Y = Year, Q = Quintal).

The findings of the study also revealed that farm size (0.351) is the strongest significant predictor of crop harvest variation among HH of the LC at 99 % CL, followed by labor (0.292), seedlings (0.198), and fertilizer (0.193) where sig-values of all the predictors were less than 0.01 (Table 3b). But the impact of oxen-power (sig = 0.19) and seed (sig = 0.47) on production variation among HH of the LC was not significant (Table 3b) due to the limited use of these inputs. This means, that over three-fourths of the total harvest of the LC was obtained from agroforestry (banana, mango, avocado, etc.,) which rarely requires oxen power-based land preparation and seed input in every growing season; that is, agroforestry requires seedlings, instead of seeds, as direct input.

Table 3c: Beta Coefficients[a] and Collinearity Statistics of Predictors of Crop Harvest in the MC

N0	Predictor Variables	Beta Coefficients			Statistics		Collinearity Statistics	
		Unstd.	**Std. E**	**Std.**	**t**	**Sig**	**Tolerance**	**VIF**
1	(Constant)	-1.102	0.479	-	-2.303	0.025	-	-
2	Farm size (ha)	0.324	0.105	0.228	3.100	0.003	0.603	1.657
3	Labor (#/HH/Year)	0.297	0.065	0.364	4.532	0.000	0.508	1.967
4	Fertilizer (kg/HH/Y)	0.151	0.074	0.148	2.057	0.045	0.630	1.587
5	Seedlings (#/HH/Y)	0.099	0.029	0.235	3.357	0.001	0.671	1.491
6	Seed (kg/HH/Y)	0.031	0.011	0.200	2.797	0.007	0.641	1.561

a. DV: Produce in Quintal/HH/Year. (**Source**: Own Analysis Using SPSS-version 20, 2020)

Labor was the strongest significant predictor of crop harvest in the MC (0.364) and UC (0.316) in 2018/19 at 99 % CL (Table 3c and Table 3d). This is due to the fact that labor in these sub-catchments is used to carry out almost all farming activities without the support of ox-power, which is a key productive force, especially in land preparation. The impact of seedlings (0.235), farm size (0.228), and seeds (0.200) on the crop harvest of the MC was also strong. But the impact of fertilizer use (0.148) on crop harvest of the MC was weak (Table 3c) as many farmers of the catchment (according to development agents) are resistant to the application of chemical fertilizer for crop farming; and this, to some extent, is also a problem of farm HH in the UC.

Table 3d: Beta Coefficients[a] and Collinearity Statistics of Predictors of Crop Harvest in the UC

N0	Predictor Variables	Beta Coefficients			Statistics		Collinearity Statistics	
		Unstd.	**Std. E**	**Std**	**t**	**Sig**	**Tolerance**	**VIF**
1	(Constant)	-4.291	0.549	-	-7.821	0.000	-	-
2	Farm size (ha)	0.377	0.133	0.182	2.836	0.006	0.179	5.597
3	Labor (#/HH/Year)	0.475	0.115	0.316	4.123	0.000	0.125	7.981
4	Fertilizer (kg/HH/Y)	0.354	0.092	0.208	3.855	0.000	0.254	3.932
5	Seedlings (#/HH/Y)	0.046	0.022	0.099	2.051	0.045	0.316	3.161
6	Seed (kg/HH/Y)	0.078	0.021	0.247	3.684	0.001	0.165	6.078

a. DV: Produce in Quintal/HH/Year. (**Source**: Own Analysis Using SPSS-version 20, 2020)

The impact of seed (0.247), fertilizer (0.208), and farm size (0.182) on the harvest of the UC was strong, too (Table 3d). Farm size (0.406) revealed the strongest impact on crop harvest variation among HH of the overall HRC, followed by labor (0.323), fertilizer (0.215), and seedlings (0.209) at 99 % CL, where sig-values of all these predictors were less than 0.01. Since production was low for HH who have limited agroforestry and who used a high level of seed, the coefficient of this predictor (seed) was negative (-0.215) in overall HRC (Table 3e).

Table 3e: Beta Coefficients[a] and Collinearity Statistics of Predictors of Harvest in the overall HRC

N0	**Predictor Variables**	**Beta Coefficients**			**Statistics**		**Collinearity Statistics**	
		Unstd.	**Std. E**	**Std**	**T**	**Sig**	**Tolerance**	**VIF**
1	(Constant)	-1.944	0.439	-	-4.43	0.000	-	-
2	Farm size (ha)	0.821	0.097	0.406	8.44	0.000	0.459	2.179
3	Labor (#/HH/Y)	0.441	0.077	0.323	5.76	0.000	0.338	2.959
4	Fertilizer	0.386	0.085	0.215	4.57	0.000	0.478	2.091
5	Seedlings	0.111	0.022	0.209	5.14	0.000	0.641	1.560
6	Seed (kg/HH/Y)	-	0.011	-	-	0.000	0.582	1.720

a. DV: Produce in Quintal/HH/Year. (**Source**: Own Analysis Using SPSS-version 20, 2020)

3.2 Discussion

The crop harvest of nature (HRC) was quantified for 2018/19, where production of the LC was slightly less than two-fold than that of the MC plus the UC of Hare. The deep, plain, alluvial, neutral to slightly alkaline fertile soils have a rich supply of nutrients (Gelaw, 2007; Glendinning, 2000; Kebede, 2012) and better farm size (0.60 ha/HH), favoring better crop harvest from the LC. The low level of crop harvest of the MC and the UC was due to the frequent use of land for growing similar crops for centuries (Assefa & Bork, 2016; Uncha, 2014), landscape steepness, severe erosion, acidic and poor soils, inadequate conservation interventions (Kebede, 2012), and smaller farm-size (0.38 ha/HH in the MC and 0.45 ha/HH in the UC) (Appendix: Table 5). Farming in the MC and UC is practiced on steep (150–300) to very steep (> 300) farm plots (FAO, 2006; Gelaw & Uncha, 2012). Constituting 70 % of the sample sites where the gradient was measured and where about 70 – 86.3 % of the existing land uses and soil conservation measures did not match the standards of the ‘treatment-oriented capability classes’ (Kebede, 2012)- a model applicable in rugged landscapes like the MC and the UC of Hare (Tegegne, 2003). The average net (crop harvest) value (US$ 643.6) of nature (HRC) was relatively low. The net value is higher where the cost of the farm inputs used for production is not assumed to be negligible (Watson, 2007; Freeman et al., 2014); for instance, where labor cost is not accounted for, the estimated net crop harvest value of nature is thought to rise by 12 – 40 % (O’Farrell et al., 2011; Shackleton et al., 2001).

4. Conclusions and Management Options

The average production and crop harvest value of nature reveal significant variations among HH of the LC, the MC, the UC, and overall HRC based on the difference in gender and farm inputs used for farming at 99 % CL. That is, the average production and crop harvest value of nature is significantly lower for female-headed HH (except in LC), for farmers having smaller HH-size, and for those who use a low amount of labor, fertilizer, farm-size, and seedlings for cultivation. The highest crop harvest variation among HH of the LC and overall HRC stems from the difference in farm size used for production as land in the LC is fertile. However, the highest crop harvest variation among HH of the MC and the UC originates from the difference in labor amount used for farming, where first, labor is uniquely used for land preparation using tsoile (a traditional hoe), without the aid of oxen-power – unlike the reality in most parts of Ethiopia; second, most crops grown in these sub-catchments are annuals requiring land preparation every harvest season. These reveal that farming in the MC and UC is labor-intensive. Fruit diseases, moisture scarcity, climate-induced spoiling of fruits, and lack of preserving technology for fruits are the main threats to farming in the LC when a decline in farm size, slope steepness, runoff erosion, limited fertilizer use, inadequate and inappropriate conservations, over-cultivation, shallow, acidic and less fertile soils are vital constraints of farming in the MC and UC. Even if the largest share (nine-tenth) of the crop revenue from HRC is accounted for by the net value of nature, the value is relatively low in comparison to the land and water potentials of the catchment; and, this (partly) reflects the inadequate attention given to the yield threats of nature by the concerned bodies.

To tackle the yield threats of nature, the government, research institutions and farm-HH should coordinate for integrated actions such as applying: (i) structural (bench terraces and stone-bunds) and agronomic measures (manure, compost, mulching and fertilizer) on steep farmlands of the MC and UC so as to curb erosion and enhance yield; (ii) water-harvest hallows, subsurface water, mulching and micro-basin so as to tackle rainfall scarcity in the LC; (iii) biological and agroforestry measures like alternating legume plants and tree-crops with annual crops (in rows/strips), grass-strips with farm-plots, etc., in all the sub-catchments; (iv) domesticating new crops from areas of similar agro-climate is also vital for improving yield; (v) economic measures like small scale fruit-packing business (based on feasibility study) is needed locally for mitigating the spoil problem of fruits; (vi) introducing new farm-tools: capable of improving labor efficiency in land preparation are essential in the MC and the UC where farmers are reliant solely on hoe-based plowing; and (vii) studies should be made about diseases/pests threatening the yield of banana and mango in the LC of Hare.

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Appendix:

Table 1a: Correlations (Pearson's) of farm inputs used per/year such as land, labor, fertilizer, seedling and seed with production quintal (Q)/year) of cropland in the Whole HRC

Variable	Measure	Produce	Land	Labor	Fertilizer	Seedling	Seed
Production (Q)	Pearson "r"	1					
	Sig. (2-t)						
Land (ha)	Pearson "r"	.85**	1				
	Sig. (2-t)	.00					
Labor (#)	Pearson "r"	.75**	.72**	1			
	Sig. (2-t)	.00	.00				
Fertilizer (kg)	Pearson "r"	.63**	.59**	.67**	1		
	Sig. (2-t)	.00	.00	.00			
Seedling (#)	Pearson "r".	.62**	.54**	.48**	.42**	1	
	Sig. (2-t)	.00	.00	.00	.00		
Seed (kg)	Pearson "r"	.28**	.28**	.55**	.42**	.21**	1
	Sig. (2-t)	.00	.00	.00	.00	.001	

**. Significance is at 0.01 level (2-tailed). (Source: the authors' computation via SPSS, 2019)

Table 1b: One-Way ANOVA about Average Crop Production Variation Based on Difference in Farm-size, Gender, Labor, HH Size and Fertilizer Used by HH of the LC

Variable	Measurement	Sum of Squares	df	Mean^2	F	Sig.
Production*farm-size	Between groups	2553.220	9	283.691	53.896	0.000
	Within groups	863.240	164	5.264		
	Total	3416.460	173			
Production*gender (Mean comparison)	Between groups	70.323	1	70.323	3.615	0.059
	Within groups	3346.137	172	19.454		
	Total	3416.460	173			
Production*labor	Between groups	2753.789	11	250.344	60.527	0.000
	Within groups	653.505	158	4.136		
	Total	3407.294	169			
Production*HH-size	Between groups	1386.209	3	462.070	38.691	0.000
	Within groups	2030.251	170	11.943		
	Total	3416.460	173			
Production*fertilizer	Between groups	1499.137	8	187.392	11.943	0.000
	Within groups	1031.582	119	8.669		
	Total	2530.719	127			

*. Significance at 0.01 level (2-tailed). Source: Computed via SPSS (Version 20), 2019

Table 1c: One-Way ANOVA about Average Crop Harvest Variation Based on Difference in Gender, HH-Size, Farm-Size, Labor and Fertilizer Amount Used for Cultivation by HH of the MC

N0	Variable/Factor	Measurement	Sum of Squares	df	Mean^2	F	Sig
I	Crop harvest*gender (Mean Comparison)	Between groups	72.179	1	72.179	21.133	0.000
		Within groups	450.836	132	3.415		
		Total	523.015	133			
II	Crop harvest*HH-size (One-way ANOVA)	Between groups	76.228	3	25.409	7.393	0.000
		Within groups	446.786	130	3.437		
		Total	523.014	133			
III	Crop harvest*farm-size (One-way ANOVA)	Between groups	297.239	5	59.448	33.703	0.000
		Within groups	225.776	128	1.764		
		Total	523.015	133			
IV	Crop harvest*labor (One-way ANOVA)	Between groups	344.037	11	31.276	23.061	0.000
		Within groups	160.033	118	1.356		
		Total	504.070	129			
V	Crop harvest*fertilizer (One-way ANOVA)	Between groups	181.421	8	22.678	8.661	0.000
		Within groups	269.686	103	2.618		
		Total	451.107	111			

***Significance at 0.01 level (2-tailed). **Source**: The Authors' Computation via SPSS (Version 20), 2019

Table 1d: One-Way ANOVA about Average Crop Harvest Variation upon Difference in Gender, HH-Size, Farm-Size, Labor and Fertilizer Amount Used for Cultivation by HH of the UC

N0	Variable/Factor	Measurement	Sum of Squares	df	Mean^2	F	Sig
I	Crop harvest*gender (Mean Comparison)	Between groups	158.296	1	158.296	13.687	.000
		Within groups	1792.634	155	11.565		
		Total	1950.930	156			
II	Crop harvest*HH-size	Between groups	608.591	3	202.864	23.122	.000
		Within groups	1342.339	153	8.773		
		Total	1950.930	156			
III	Crop harvest*farm-size	Between groups	1701.629	7	243.090	145.288	.000
		Within groups	249.301	149	1.673		
		Total	1950.930	156			
IV	Crop harvest*labor	Between groups	1823.361	11	165.760	344.861	.000
		Within groups	66.811	139	.481		
		Total	1890.172	150			
V	Crop harvest*fertilizer	Between groups	1150.827	8	143.853	45.557	.000
		Within groups	296.823	94	3.158		
		Total	1447.650	102			

***Significance at 0.01 level (2-tailed). **Source**: Own Computation via SPSS (Version 20), 2019

Table 1e: One-Way ANOVA on Average Crop Production Variation Based on Difference in Farm-Size, Gender, HH-Size, Labor and Fertilizer Amount Used for Farming by HH in Overall HRC

Variable	Measurement	Sum of Squares	Df	Mean^2	F	Sig.
Production* Farm size	Between Groups	12074.322	9	1341.591	90.229	.000
	Within Groups	6765.256	455	14.869		
	Total	18839.578	464			
Production* Gender (Mean comparison)	Between Groups	502.513	1	502.513	12.688	.000
	Within Groups	18337.065	463	39.605		
	Total	18839.578	464			
Production* Labor	Between Groups	7104.226	12	592.019	22.799	.000
	Within Groups	11373.738	438	25.967		
	Total	18477.965	450			
Production* HH size	Between Groups	1812.716	3	604.239	16.725	.000
	Within Groups	16619.162	460	36.129		
	Total	18431.877	463			
Production*Fertilizer	Between Groups	3791.546	8	473.943	13.504	.000
	Within Groups	11722.553	334	35.097		
	Total	15514.099	342			

*****Significance at 0.01 level (2-tailed). **Source**: Own Computation via SPSS (Version 20), 2019

Table 1f: One-Way ANOVA on Average Crop Value/Income Variation based on Difference in Farm-Size, Gender, Labor, HH-Size and Fertilizer Amount Used for Cultivation by HH in Overall HRC

Variable	Measurement	Sum of Squares	Df	Mean^2	F	Sig.
Value*farm-size	Between groups	1905.697	9	211.744	88.510	0.000
	Within groups	1088.510	455	2.392		
	Total	2994.206	464			
Value*gender	Between groups	115.268	1	115.268	18.538	.000
	Within groups	2878.939	463	6.218		
	Total	2994.206	464			
Value*labor	Between groups	1315.926	12	109.660	29.724	0.000
	Within groups	1615.893	438	3.689		
	Total	2931.818	450			
Value*HH-size	Between groups	323.996	3	107.999	18.904	0.000
	Within groups	2627.995	460	5.713		
	Total	2951.991	463			
Value*fertilizer	Between groups	697.253	8	87.157	18.039	0.000
	Within groups	1613.721	334	4.831		
	Total	2310.974	342			

*. Significance at 0.01 level (2-tailed). Source: Computed via SPSS (Version 20), 2019

Table 4a: Result of the T-test for Comparison between HH of the LC Vs., MC using Average Production (Quintal/HH/Year) and Average Value/Income (US$/HH/Year) from Crop Harvest, HRC

Variable	**Assump**	**Levene's TEV**		**T-test for Equality of Means**						
		F	**Sig**	**T**	**df**	**Sig (2t)**	**MD**	**Std. ED**	**99% CI of Difference**	
									Lower B	**Upper B**
Production (Q)	EVA	84.89	0.000	10.04	306.00	0.000	7.20	0.72	5.34	9.05
	EVNA			11.28	199.36	0.000	7.20	0.64	5.54	8.85
Value (US$)	EVA	52.99	0.000	7.56	306.00	0.000	1.14	0.15	0.75	1.53
	EVNA			8.31	239.12	0.000	1.14	0.14	0.78	1.49

*At 99 % confidence interval (Note: Assum = Assumption, TEV = Test for Equality of Variance; EVA = Equality of Variance Assumed; EVNA = Equality of Variance Not Assumed) (Source: The Authors' Analysis via SPSS, 2019)

Table 4b: Result of the T-test for Comparison between HH of the LC Vs., UC using Average Production (Quintal/HH/Year) and Average Value/Income (US$/HH/Year) from Crop Harvest, HRC

Variable	**Assump**	**Levene's TEV**		**T-test for Equality of Means**						
		F	**Sig**	**T**	**df**	**Sig (2t)**	**MD**	**Std. ED**	**99% CI of Difference**	
									Lower B	**Upper B**
Production (Q)	EVA	45.88	0.000	9.06	329.00	0.000	6.35	0.70	4.53	8.16
	EVNA			9.38	241.73	0.000	6.35	0.68	4.59	8.10
Value (US$)	EVA	26.99	0.000	6.83	329.00	0.000	1.02	0.15	0.63	1.41
	EVNA			7.01	281.11	0.000	1.02	0.15	0.64	1.40

*At 99% confidence interval (Note: Assum = Assumption, TEV = Test for Equality of Variance; EVA = Equality of Variance Assumed; EVNA = Equality of Variance Not Assumed) (Source: The Authors' Analysis via SPSS, 2019)

Table 4c: Result of the T-test for Comparison between HH of the MC Vs., UC using Average Production (Quintal/HH/Year) and Average Value/Income (US$/HH/Year) from Crop Harvest, HRC

Variable	**Assump**	**Levene's TEV**		**T-test for Equality of Means**						
		F	**Sig**	**T**	**df**	**Sig (2t)**	**MD**	**Std. ED**	**99% CI of Difference**	
									Lower B	**Upper B**
Production (Q)	EVA	38.08	0.000	-2.47	289.00	.014	-0.85	0.34	-1.74	0.04
	EVNA			-2.57	252.00	.011	-0.85	0.33	-1.71	0.01
Value (US$)	EVA	15.43	0.000	-1.20	289.00	.229	-0.12	0.10	-0.37	0.13
	EVNA			-1.24	278.35	.217	-0.12	0.09	-0.36	0.13

*At 99% confidence interval (Note: Assump = Assumption, TEV = Test for Equality of Variance; EVA = Equality of Variance Assumed; EVNA = Equality of Variance Not Assumed) (Source: The Authors' Analysis via SPSS, 2019)

Table 5: Average Production, Revenue and Net Value of Crops, and Input Cost and Farm-Size of HH

Area	**Production/Harvest (Q/HH/Year)**				**Average (US$/HH/Year)**			**Average (ha/HH)**
	Max	**Min**	**Range**	**Mean**	**Revenue**	**Net Value**	**Input Cost**	**Farm-Size**
LC	119	5	114	35.4	981.9	907.3	74.6	0.60
MC	32	2	30	10.3	505.2	455.1	50.2	0.38
UC	44	2	42	13.1	567.9	512.3	55.6	0.42
HRC	119	2	117	20.6	704.8	643.6	61.1	0.48

Source: The Author's Summary (2019) (**Note**: Max= Maximum. Min=Minimum. Q = Quintal)

Table 6a: Average Unit (AU) and Total Cost of Seeds and Seedlings Used by HH of the LC, 2018/19

N0	Seeds and Seedlings	HH		Amount(kg/#)		AU and Total Cost (US$)		
		N	P (%)	Average	Total	AU	Total	P (%)
1	Banana (#)*	54	31.0	33.0	1,782.0	0.22	392.1	
2	Mango (#)*	51	29.3	20.0	1,020.0	0.25	255.0	
3	Maize (kg)**	67	38.5	17.3	1,159.1	0.38	443.5	
4	Onion (kg)**	46	26.4	19.7	907.6	0.21	191.1	
	Total						**1,281.7**	

Source: The Authors' Computation (2019) (**Note:** * = Seedlings; ** = Seeds)

Table 6b: Cost of Seeds and Seedlings by HH of the MC of Hare for 2018/19 production Season

N0	Seeds and Seedlings	HH		Amount(kg/#)		Unit and Total Cost (US$)		
		N	P (%)	Mean	Total	Unit	Total	P (%)
1	Barley (kg)**	41	30.6	23.3	955.3	0.33	315.2	
2	Wheat (kg)**	34	25.4	15.1	513.4	0.44	225.9	
3	Apple (#)*	20	14.9	32.0	640.0	0.93	595.2	
4	Bean (kg)**	22	16.4	14.3	314.6	0.44	138.4	
5	Pea (kg)**	20	14.9	12.7	254.0	0.58	148.0	
6	Potato (kg)**	42	31.3	29.6	1,243.2	0.15	186.5	
	Total (US$)	**-**	**-**	**-**	**-**		**1,609.2**	

Source: The Authors' Computation (2019) (**Note**: * = Seedlings; ** = Seeds; AUC = Average Unit Cost)

Table 6c: Cost of Seeds and Seedling Used by HH of the UC in 2018/19 Production Season

N0	Seeds & Seedlings	HH		Amount (kg/#)		Unit and Total Cost (US$)		
		N0	P (%)	Mean	Total	AU	Total	P (%)
1	Barley (kg)**	47	29.9	21.8	1,024.6	0.34	348.4	
2	Wheat (kg)**	32	20.4	17.3	553.6	0.46	254.7	
3	Bean (kg)**	21	13.4	14.1	296.1	0.42	124.7	
4	Pea (kg)**	17	10.8	15.9	270.3	0.58	156.6	
5	Apple (#)	23	14.6	28	644	0.93	598.0	
6	Potato (kg)**	39	24.8	36.1	1,407.9	0.15	211.2	
	Total						**1,693.6**	

Source: The Authors' Computation (2019) (Note: * = Seedlings; ** = Seeds; AUC = Average Unit Cost)

Table 6d: Labor, Fertilizerand Water Pump Cost Used by Farm-HH of the LC, MC and UC for 2018/19

N0	Area	HH	Day Laborer (#)		Labor Cost (US$)		Fertilizer and WPM Cost (US$)			Sum
			Mean	Total	Mean	Total	DAP	Urea	WPM	(US$)
1	LC	86	82	7,052	0.97	6,831.7	2,292.6	1,320.6	1,252.4	11,697.3
2	MC	38	43	1,634	1.03	1,683.0	2,039.4	1,388.9	0	5,111.3
3	UC	48	69	3,312	1.03	3,411.4	2,177.6	1,447.5	0	7,036.5
4	**HRC**	**172**	**-**	**-**		**11,926.1**	**6,509.6**	**4,157.0**	**1,252.4**	**23,845.1**

Source: The Author'sSummary (2019) (**Note:** DAP = Di-ammonium Phosphate. WPM = Water Pump Motor)

Table 6e. Summary of Farm Inputs' Cost of HH of the LC, MC, UC and HRC in 2018/19 Season

Farm Input	LC		MC		UC		HRC (Total)	
	US$	P (%)	US$	P (%)	US$	P (%)	US$	P (%)
Labor	6,831.7	52.6	1,683.0	25.0	3,411.4	39.1	11,926.1	42.0
Fertilizer	3,613.2	27.8	3,428.3	51.0	3,625.1	41.5	10,666.6	37.5
Seed and seedlings	1,281.7	9.9	1,609.2	24.0	1,693.6	19.4	4,584.5	16.1
Water pump motor	1,252.4	9.7	0.0	0.0	0.0	0.0	1,252.4	4.4
Total	**12,979.0**	**100.0**	**6,720.5**	**100.0**	**8,730.1**	**100.0**	**28,429.6**	**100.0**

Source: Own Summary, 2019/20

Table 7: Agro-climate Categories of HRC

N0	Agro-climate	Altitude (m)	Area (ha)	P (%)	Sub-catchment
1	*Wurch* (afro-alpine)	3200 - 3484	937.2	4.0	UC
2	*Dega* (temperate)	2300 - 3200	1,1318.0	48.3	UC (38.6%) MC (9.7%)
3	*Woina-Dega* (sub-tropical)	1500 - 2300	5,553.6	23.7	MC
4	*Kolla* (tropical)	< 1500	5,623.9	24.0	LC
	Total		23,432.7	100.0	

Source: Based on Own Field Survey data, and Evidences from Hurni (1998) and Yechale (2012)

Table 9: Landscape Configuration (Slope) Categories of HRC

N0	Landscape Configuration (Slope)	Area (ha)	P (%)
1	Gently sloping to sloping, < 5˚ (8.3%)	7,475.0	31.9
2	Strongly sloping to moderately steep, 5 - 15˚ (8.3 - 25%)	13,075.5	55.8
3	Steep (15 - 30˚ or 25 – 50%) to very steep (> 30˚ or 50%)	2,882.2	12.3
	Total	23,432.7	100

Source: The Authors' Analysis via Arc GIS 9.3 (2018) upon Slope Gradient Classes of FAO (1990)