# Analysis of the Values and Impacts of Ecosystem Services Dynamics, and Valuation of Selected Provisioning Services in Hare River Catchment, Southern Ethiopia

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**March, 2019**

**Addis Ababa,**

**Ethiopia**

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**Addis Ababa University**

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**Department of Geography and Environmental Studies**

## Declaration:

The undersigned declare that this is my original work, has not been presented for a degree at any level in any other university and that all resource materials used for this dissertation have been duly acknowledged.

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**Abren Gelaw Mekonnen**

This dissertation has been submitted for examination with my approval as a university advisor.

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**Singh K.N. (Ph.D)**

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## Acronyms:

ANOVA = Analysis of Variance

AR = Annual Rate (of change)

ASL = Above Sea Level

C = Charcoal

CFWC = Crop, Fire-Wood and Charcoal

CI = Confidence Interval

CPS = Current Provisioning Services

CS = Coefficient of Sensitivity

CV = Coefficient of Variation

DA = Development Agent

DANRP = Department of Agriculture and Natural Resource Protection

ES = Ecosystem/Environmental Service

ESV = Ecosystem/Environmental Service Value

ETB = Ethiopian Birr

FWC = Fire-Wood and Charcoal

FW = Firewood

GNP = Growth National Product

HH = Households

HRC = Hare River Catchment

Kg/HH/Y = Kilogram per Household per Year

KPA = *Kebele* Peasant Administration (that is, the smallest political administrative unit in Ethiopia)

LC = Lower Catchment

M = Magnitude

MAE = Meteorological Agency of Ethiopia

MAT = Mean Annual Temperature

MC = Middle Catchment

MEA = Millennium Ecosystem Assessment

MP/Q = Mean Price per Quintal

MMRF = Mean Monthly Rain-Fall

MMT = Mean Monthly Temperature

MSS = Multi Spatial and Spectral

MU = Middle and Upper Catchment

NBE = National Bank of Ethiopia

NEV = Net Economic Value

PES = Payments for Ecosystem Services

Q/Y = Quintal per Year

SD = Standard Deviation

TM = Thematic Mapper

UC = Upper Catchment

US$ = United States' Dollar

VC = Valuation Coefficient

WOA = *Woreda* Office of Agriculture [Hierarchically, *Woreda* is a higher administrative unit next to *Kebele* - the smallest level of unit in the political administrative structure of Ethiopia]

WPM = Water Pumping Motor

WTP = Willingness to Pay

## Abstract

*Degradation of environmental services is a salient feature of Ethiopia and Hare Catchment. So, this study was aimed at analyzing magnitudes of ESV dynamics, and level of earnings from crop and fuel-wood products in HRC. Remote sensing sources, questionnaire (survey of 465 HH), interview, etc., were used for data acquisition. LULC data were extracted using Arc GIS (9.3). Sensitivity analysis was used to prove accuracy of estimated values of ecosystem service changes (1967 – 2015) computed upon change matrix data and value coefficients of Costanza et al., (1997). Correlation, t-test, ANOVA and regression were used for data analysis via SPSS. HRC experienced a net ESV loss of US$ 7.039 million and declining trend of service value within 1967 – 2015; and, where the lion's share of the ESV loss was triggered by cropland expansion at the cost of natural resources. The impact of ESV loss was rising temperature (by 0.5 – 0.6 $^{0}$C) and rainfall (by 104 - 214.8mm), and decline discharge of Hare River (by 689,000 m$^{3}$). "Farm size" in LC and overall HRC, and "labor" in the MC and UC" were the strongest significant predictors of crop harvest at 99% confidence interval (CI). Location (Sub-catchment) difference, "gender," "HH size," "farm size," "labor" and "fertilizer" use difference-based variation of average yield and income from crop harvest among HH of HRC was significant at 95% CI. Amount of fuel-wood consumption also revealed significant variation upon variation in HH-size and income status of HH at 95 CI. Average income from both crop and fuel-wood products revealed significant variation among HH of HRC at 99% CI based on disparity in gender, family-size and location (Sub-catchment). Current (2015/16) average income (US$ 877.3 per/HH) from crop and fuel-wood products of HRC was somewhat low due to dwindling ecological services overtime. Thus, stakeholders should focus on agro-forestry options and payments for ecological services-based resilience of degraded resources of HRC, Southern Ethiopia.*

***Key words**: Ecosystem service, loss, trend, harvest, income, smallholder farmer, average, cropland, net economic value, fuel-wood, etc.*

# Chapter One

# Introduction

## 1.1 Background

Nature provides diverse services for human beings; and, ensuring the sustainability of the services is a critical challenge worldwide (MEA, 2005). Here, it is necessary to pinpoint what goods and services of nature are and the rationale behind the valuation concept of environmental services.

Goods and services are the varying benefits peoples obtain from nature such as crop products, water supply, fuel-products, bio-chemicals, fruits, nutrient cycle, air quality control, climate regulation, etc., (MEA, 2005b; Newcome et al., 2005; Egoh et al., 2012). The notion of valuing most environmental services was not a major research agendum until the last decades of the 20$^{th}$ C (Costanza et al., 1997). The valuation concept of ecological benefits has emanated from the fact that most services of nature were non-marketed (Portela and Rademacher, 2001) and, hence, were either overlooked or undermined in the estimation of GNP and also in the formulation of policies on resources management (Costanza et al., 1997; Alexander et al., 1998). In fact, economic values were not assigned for non-marketed services; this is so because, applying existing economic tools had been hardly simple to measure values of such goods/services until some decades-past (De-Groot et al., 2002; Turner et al., 2008; Boyd, 2012; Moore et al., 2011). So, economic valuation is necessitated as values could not be observed through the "lens of market transaction" (Boyd, 2012) for those goods and services that are not exchanged in formal markets(Boyd, 2012; Moore et al., 2011). Valuation of marketed and non-marketed services enable appreciation of their values upon concrete evidences (financially) and communicating the wider society about threats of natural resources in terms of money (Freeman, 2003; Boyd, 2012).

Economic valuation of environmental services was also necessitated due to unsustainable exploitation ofnatural resources in most developing countries (WEHAB, 2002;MEA, 2005). That is, ecological services have been progressively dwindling due to overburden by increasing human population and unwise use of resources (WEHAB, 2002;MEA, 2005; Mahmud et al., 2005); in this regard, it was revealed that 50% of the global wetlands has got drained (within 1970 – 1999), about three-fourth of the genetic diversity of crops domesticated globally has vanished, and one-fifth of the fish species of the earth's freshwater went to extinction(WEHAB, 2002); it was also shown that over 60% of the overall benefits (people have been deriving from nature) had got depleted globally(MEA, 2005). This was

observed as resources (ecosystems) were not accounted as natural capital assets (Gomez-Baggethun and De Groot, 2010); that is, ecological systems have to be considered as natural capital assets as they are bases for the sustainable flow of diverse services for people(Gomez-Baggethun and De Groot, 2010).Quantifying service values of nature(financially) is thought to be significant for appropriate decisions on policy issues; this is because, the costs and benefits of natural services shall be considered in the formulation of policies about management of resources and the environment (MEA, 2003; Boyd, 2012).

Measuring non-marketed ecological services was a critical challenge since such benefits have no market value (price) (Boyd, 2012). So, Costanza and others designed a model, that is, Valuation Coefficients (VC) for services (marketed and non-marketed services) derived from the varying biome classes of the world (Coztanza et al., 1997); and, it was used to estimate the total value of services obtained from all biome categories of the globe, which was US$ 33 trillion per year; and, this value was a bit less than two fold of the GNP of the world, which was about US$ 18 trillion per annum, then (ibid).Croplands were assigned to offer an estimated service value of US$ 92 per/ha/year about two decades ago, and the value allocated to(an average) forest was US$ 969 per/ha/year (Costanza et al., 1997). The estimated ecosystem service value of the world (33 trillion) was criticized for over-exaggeration (Alexander et al., 1998); hence, it was estimated to range within 44 – 88% of the planet's GNP by the same group of researchers (Alexander et al., 1998). Service value coefficients allocated for the global biome classes have been used as bases for quantifying level of service value and its dynamics (gain/loss) overtime by catchment level studies (Zou et al., 2005; Yuan-wang et al., 2006; Tian-hong et al., 2010; Costanza et al., 2014; Kindu et al., 2016). But, valuation studies on local level environmental services are still limited in many Sub-Sahara nations of Africa (Egoh et al., 2012).

LULC dynamics and degradation of natural resources is frequent in Ethiopia (Belay, 2002; Wondamlak, 2002; Muluneh, 2003). Studies accustomed to measuring cost of resource degradation (Mohamed et al., 2005), LULC change-induced loss of ecological service values (Kindu et al., 2016) and valuing the provisioning services of nature (Watson, 2007), financially, were limited in Ethiopia. LULC change–led dwindling natural resource condition has also been a critical problem in Hare River Catchment (HRC), Southern Ethiopia (Yechale, 2012; Abera, 2014). But studies aimed at measuring value losses of ecological services in response to LULC dynamics, and quantifying current earnings from provisioning services of cropland and forest ecosystems were rare in the area (HRC).

## 1.2 Statement of the Problem and Justification

Nature provides benefits ranging from provisioning through supporting and regulating to cultural services (MEA, 2005b; Schroth and McNeely, 2011). Several studies have been conducted about values of Ecosystem Services (ES) dynamics (Kreuter et al., 2001; Tian-hong et al., 2010; Costanza et al., 2014; Kindu et al., 2016) and valuation of current services of nature in different areas (Dovie et al, 2005; Watson, 2007; O'Farrell et al., 2011). However, the studies (in some cases) reveal thematic, spatial and/or methodological differences in addressing the problems investigated.

Environmental services and their values undergo change in response to the dynamics in LULC and overall ecological environment (MEA, 2005; Costanza et al., 2014). Magnitudes and rates of ESV gain/loss impacted by LULC dynamics have been measured by several studies (Kreuter et al., 2001; Yuan-wang et al., 2006; Li et al., 2007; Chanhda et al., 2009; Tian-hong et al., 2010; Yun-guo et al., 2011; Costanza et al., 2014; Kindu et al., 2016). However, research works of this kind couldn't be said adequate especially in many Sub-Sahara Africa nations where the livelihood means of most people is strongly linked to the goods/services directly acquired from nature (Egoh, 2002; Kideghesho et al., 2006; Egoh et al., 2012). In fact, a number of studies revealed limitations in measuring the synergic effect of LULC changes on ESV gains or losses, which was due to failure application of the "change matrix" model for estimating magnitudes of net values of ES dynamics (Kreuter et al., 2001; Zou et al., 2005; Yuan-wang et al., 2006; Li et al., 2007; Chanhda et al., 2009; Kindu et al., 2016). Use of "change matrix" model for estimation enables considering "valuation coefficient" difference between the original and the new LULC classes while computing the net value gains/losses of ecological services impacted by LULC changes (Yun-guo et al., 2011).

Results obtained through application of the change matrix model are also reliable indicators of the immediate change drivers of value gains/losses of environmental services (Yun-guo et al., 2011). Ecological service dynamics could be triggered by deforestation for fuel-wood and timber, expansion of crop farming, poverty, resource over-use (Belay, 2002; Geist and Lambin, 2002; Randolph et al., 2005; Kideghesho et al., 2006; Shackleton et al., 2008; Abate, 2011; Binyam, 2015), rainfall variability, state policy, settlement and infrastructure expansion, invasion of alien species, drought, chemical farm inputs (Pimentel et al., 2000; Geist and Lambin, 2002; Newcome et al., 2005; Egoh et al., 2012), etc. But, assessing the drivers of ES dynamics is of great worth since the type and degree of impact of change

drivers couldn't be the same everywhere across the globe (Turner et al., 2000; Lambin et al., 2003; MEA, 2005).

Investigating the benefits obtained from croplands, forest/woodland, etc., was a vital point of emphasis by several studies across the world (Appasamy, 1993; Metz, 1994; Pimentel et al., 1997a; Bishop, 1999; Dovie et al, 2005; Watson, 2007; Moore et al., 2011; O'Farrell et al., 2011). Assessing the products generated from cropland, the services on which it depends, and its adverse effects were major areas of analyses by studies related to agro-ecosystems (croplands) (Antle and Capalbo, 2002; Zhang et al., 2007; Swinton et al., 2007; Power, 2010; Norris et al., 2010; Foley et al., 2011; Garbach et al., 2014). Croplands were assessed from the viewpoint of the services they provide to people and environment such as food, biofuel and fiber for consumption (MEA, 2005b; O'Farrell et al., 2011), pollination, biological pest control, landscape beauty, habitat provision, control of water supply, etc., (MEA, 2005;Tscharntke et al., 2005; Zhang et al. 2007; Power, 2010). Investigations were also made about the contribution of croplands to improvement of peoples' livelihood status and reduction of food insecurity challenges by a number of studies (Shackleton et al., 2001; Abren, 2007; Altieri et al., 2012; IFPRI, 2012; Abera, 2014). However, Catchment (local) and HH level studies that have measured cropland products and net economic values of nature through crop harvest were limited (from the viewpoint of spatial coverage) especial in many Sub-Sahara countries of Africa.

Quantifying net value of cropland services requires deducting the cost of inputs used for acquisition of the products (Freeman, 2003). Measurement of net values of crop harvest by some studies were made without considering input costs of wage labor (Dovie et al, 2005; Watson, 2007), improved seeds and fertilizer (Watson, 2007). Many farmers spend cash for application of fertilizer (Jayne et al., 2003), seeds/seedlings (Spielman et al., 2012), compost, wage labor (Watson, 2007), etc., on croplands. So, the costs of such inputs have to be accounted while measuring the net value of nature through crop harvest (Shackleton et al., 2001; Freeman, 2003). Here, farm inputs are applied on cropland simply that crop harvest is a function of the various inputs used for production (Watson, 2007; Yu et al., 2010; Spielman et al., 2012); hence, the impact of farm inputs (like labor, fertilizer, seed, land, etc.,) on amount of crop harvest have to be quantified so as to understand (upon empirical evidences) the contribution of each farm input to the total annual production.

Services of forest/woodland resources were measured by studies made in different areas of the earth (Pimentel et al., 1997a; Bishop, 1999; Moore et al., 2011). Forest/woodland products used for domestic

energy consumption and construction purposes were quantified by numerous studies (Appasamy, 1993; Metz, 1994; Pimentel and Wightman, 1999; FAO, 2001; Pearce, 2001; Sampson et al. 2005; Madubansi and Shackleton, 2006; Nautiyal and Kaechele, 2008; Swanson and Chapin, 2009). But, studies that have measured contributions of fuel-wood, timber, food, bio-chemicals, etc., services of forest and woodland to the income status of HH and/or economy (GDP) of developing nations (Peskin et al., 1992; Vedeld et al., 2004; Dovie et al., 2005; Mamo et al., 2007) could not be said adequate in their spatial coverage. Specifically speaking, over 50% of the global wood utilization is used for domestic energy consumption (Sampson et al. 2005); but it is difficult to say that the level of contribution of fuel-wood products of forest/woodland to the income status of HH is adequately recognized in some Sub-Saharan nations of African, such as Ethiopia.

Several studies were conducted about the impact of LULC dynamics on crop yield, soil fertility, biodiversity, etc., in Ethiopia (Solomon, 1994; Kibrom and Hedlund, 2000; Badege, 2001; Belay, 2002; Meles et al., 2008; Abate, 2011; Eleni et al., 2013; Denberu, 2015; Binyam, 2015; Kindu et al., 2016; etc.). However, studies which have measured LULC dynamics-led value loss of ecological services (except Kindu et al., 2016), and its impacts on climate and hydrology were rare. Studies aimed at measuring economic values of different services of nature were also limited in Ethiopia: cost of land degradation-Highlands of Ethiopia (Mohamed et al., 2005), value of crop, livestock and forest products - Bale Highlands (Watson, 2007), valuing pollination service for coffee production (FAO, 2006), measuring irrigation service value through Willingness to Pay (WTP) for Catchment conservation - Gojam (Habtamu, 2009), and quantifying potable water supply services upon WTP for forest conservation – Wondo-Genet (Bamlaku, 2014) were among those valuation-related studies in Ethiopia. Although researches conducted about cropland-related issues were several in Ethiopia and HRC (Mohamed et al., 2005; Watson, 2007; Abren, 2007; Seifu et al., 2014; Abera, 2014; Assefa and Bork, 2016; etc.), those which have quantified the net values of nature through crop-harvest (Watson, 2007) were limited. Studies aimed at evaluating the impact of farm inputs on amount of crop harvest were also rare in Ethiopia and HRC even if level of harvest is a function of diverse HH-related economic variables such labor, fertilizer, seed, farm-size, etc., (Watson, 2007; Yu et al., 2010; Spielman et al., 2012).This kind of evaluation is valuable for devising options (or recommendations) about farm-inputs and yield related problems of croplands. Similarly, level of use and value of consumptive services of forest and woodland (fuel-wood, timber, etc.,) were quantified by some studies in Ethiopia (Mamo et al., 2007; Watson, 2007; Babulo et al., 2009; Tesfaye et al., 2011) even if spatial coverage of such studies was

limited in the country. Studies made about the contribution of fuel-wood products to the income status of HH were little in HRC. Understanding economic value of ecological service degradation, its impacts on climate and hydrology, and current net value of nature through crop harvest and fuel-wood services of HRC, therefore, necessitated inquiry about the matter (Boyd, 2012).

HRC was preferred for investigation over other Catchments of Ethiopia due to the justifications pinpointed below too: first, LULC dynamics and degradation of natural resources, being critical and persistent challenges of HRC (Yechale, 2012; Denberu, 2015; Assefa and Bork, 2016), impress researchers who are curios in problems of environmental resources. Second, production and yield of croplands in middle and upper Sub-catchments of HRC (Gamo-highlands) was indicated to have been largely poor due to cultivation on steep slopes (over $30^0$ in some cases), sever runoff erosion, acidic and poorly fertile soils (Abren and Abera, 2012; Yechale, 2012), inadequate and inappropriate (in some cases) soil and water conservation interventions (Yechale, 2012), decreasing farm-size and increasing fragmentation of land, and farmers' resistance and/or low purchasing-power for application of chemical fertilizers (Abera, 2014). Third, the middle and upper Sub-catchments, being part of Gamo-highlands, have been threatened by food insecurity problem even if the proportion of HH who requires (or receives) food aid annually varies overtime (Abera, 2014). Therefore, the (three) sets of problems (highlighted in this paragraph above) and the other gaps substantiated in the previous paragraphs of the problem statement have initiated the researcher to prefer HRC (for inquiry) over the other Catchments in Ethiopia.

## 1.3 Objectives of the Study

The general objective of this research was to comprehend the economic values and impacts of Ecosystem Services (ES) dynamics, and valuation of selected provisioning services of HRC, Southern Ethiopia. Specific objectives of the study were:

1) To analyze the magnitude of value changes and impacts of ecosystem services dynamics in HRC within 1967 – 2015;
2) To evaluate whether the estimated value (US$/HH/year) of nature, through crop harvest, reveal significant variation among HH of HRC (Lower Catchment _LC, Middle Catchment _MC and Upper Catchment _UC) upon difference in gender, HH-size, Sub-catchment and farm-inputs (farm-size, seeds, oxen-power, seedlings, labor and fertilizer) used for production;

3) To measure the distribution/variation of estimated fuel-wood (firewood and charcoal) products' value (US$/HH/year) of nature among rural HH of HRC and its Sub-catchments;
4) To appraise whether gender, HH size, farm-size and Sub-catchment difference-based variation of average value (US$/HH/year) of nature through crop harvest and fuel-wood consumption was statistically significant among HH of the LC, MC, UC and overall Catchment.

## 1.4 Basic Research Questions

The following basic research questions were formulated upon the problems stated and objectives set:

1) How was the magnitude and trend of value of ecological service dynamics in HRC in response to LULC changes within 1967 – 2015? Was the trend of value of ES changes a gain or loss? What was/were the main driving force/s for the gain/loss of ESV in the Catchment? How was the impact of ESV changes on annual temperature, rainfall and river discharge in the area?
2) How much was the estimated value (US$/HH/year) of nature through crop harvest by rural HH of the LC, MC, UC and overall HRC? Was gender, HH-size and Sub-catchment difference-based variation of income (US$/HH/year) from crop harvest statistically significant among HH of HRC? How much share (%) of the 2015/16 total crop harvest was significantly predicted by farm-size, labor, oxen-power, seeds, seedlings and fertilizer used for production? Which farm input/s was/were the strongest significant explanatory variable of crop "produce/harvest?"
3) To what extent was the estimated fuel-wood consumption value (US$/HH/year) of nature for rural HH of the LC, MC, UC and HRC? Was the variation of income (US$/HH/year) from fuel-wood products statistically significant in the Sub-catchments and overall study area?
4) How much was the average estimated value (US$/HH/year) of nature through crop harvest and fuel-wood products of HRC? Was there a statistically significant variation in average value or income (US$/HH/year) from these products among HH of the LC, MC, UC and overall HRC upon differences in gender, HH-size, farm-size and location/Sub-catchments?

## 1.5 Significance of the Study

The motive behind most research works originates from the need to devise alternative solutions for the problems investigated. So, this study provides multiple benefits as it:

- Would be used by policy makers (at national and regional levels) for the formulation of policies targeted towards resilience of degraded ecological resources;

- Mirrors planners (in conservation and management of resources, biodiversity and environment) the interventions through which depleted natural resources are rehabilitated so that biodiversity and ecological functions (like hydrological and nutrient cycle) of HRC gets recovered, the flow of ES is improved, and variability of micro-climate could also be minimized;
- Points to planners (in "sustainable land management" and "crop production") the options by which management and productivity-related challenges of croplands are surmounted, and thus, production and productivity of land would be improved;
- Provide information on potential and extra areas of concern for further research in the Catchment where this study was conducted; and,
- Be used as a spring-board for scholars who are curios in thematic areas related to valuation of ES and their dynamics overtime; that is, the methods used for measuring and analyzing the ecological service value changes (gains/losses) and values of selected (current) cropland and forest/woodland services of HRC could be employed by other researchers who are interested in areas related to these issues.

To sum up, the findings about values of ES losses, and current crop and fuel-wood products of HRC is valuable for communicating the challenges of ES degradation to stakeholders (policy makers, planners, farmers, etc.) upon concrete evidences in terms of money and also, for mobilizing them for restoration and sustainable use of natural resources and the environment.

## 1.6 Organization of the Dissertation

This dissertation is about "Analysis of the Dynamics of Ecosystem Services, and Valuation of Selected Consumptive Services in Hare River Catchment, Southern Ethiopia." It is organized in monograph format. It consists of seven chapters. The first (introductory) chapter is composed of background, problem statement, objectives, basic research questions, significance of the study and organization of the dissertation. Conceptual and theoretical frameworks and empirical research literature of the dissertation are reviewed, illustrated and organized in chapter two. Chapter three is composed of description of study area, research approach and design, data sources, methods of data acquisition, the sampling design and techniques of data analysis, assumptions and ethical issues.

"Analysis of Ecosystem Service (ES) dynamics in HRC" is presented in chapter four, which consists of "status of ESV of HRC during 1967– 2015," "magnitudes, trends and drivers of ESV dynamics,

"sensitivity analysis about the estimated ESV changes," "impacts of ESV dynamics (loss)" and "discussion" on results. Chapter five is about "valuation of cropland provisioning products of HRC;" that is, in this chapter, "produce and revenue/income from croplands," "cost and Net Economic Value (NEV) of cropland produces," "impact of farm inputs (predictors) on cropland produce/harvest," and "discussions" were presented. Chapter six presents about "values of selected provisioning services of forest/woodland in HRC;" in this chapter, "level of firewood and charcoal consumption," "economic value of firewood and charcoal services," and "discussions" were presented. The distribution and variation of income from crop and fuel-wood products (both at Sub-catchment and overall HRC levels) is presented in Chapter seven. In chapter eight, conclusive remarks have been pinpointed based on major findings of the study about "ESV dynamics," "values of cropland services (harvest),"and "amount of fuel-wood services and income from the services." Finally, alternative (suggestive) solutions were forwarded about major problems related to ecological resources and the services obtained from them.

# Chapter Two

# Review of Literature

## 2.1 Conceptual and Theoretical Frameworks

### 2.1.1 Conceptual Framework:

Assessing the dynamics and values of services of nature requires understanding the basic concepts used in the study such as ecosystem goods and services, dynamics of Ecosystem Service Value (ESV), change drivers of ESV, agro-ecosystems (croplands), values and valuation techniques of environmental services (say cropland, forest, etc.,), and others.

An *ecosystem* is a distinct area where living things interact each other and also with the non-living attributes (MEA, 2005). It is a unit area where plants and animals interact (for services) one-another and also with abiotic (soil, water, energy, etc.,) entities. Ecosystems provide diverse goods and services to people (MEA, 2005a; Hopkin et al., 2011; Egoh et al., 2012). That is why *ecosystems* are considered as a *natural capital*, that is, a stock from which natural income (that is, services) flows continuously (Gomez-Baggethun and De Groot, 2010). *Ecosystem goods/services* are the varying benefits people derive from ecosystem processes or functions (Newcome et al., 2005; Li et al., 2007; Egoh et al., 2012). Technically, *goods* differ from *services* although the terms are often used interchangeably (Haines-Young and Potschin, 2009; Boyd, 2012). *Goods* refer to the concrete or physical products derived out of ecosystem functions; whereas, *services* often incorporate intangible or non-observable benefits of nature (Brown et al., 2007; Haines-Young and Potschin, 2009).

There have been differences in the classification of environmental (ecosystem) services among scholars. The widely acknowledged classification is the one which has categorized ecosystem benefits into provisioning, supporting, regulatory and cultural goods/services (MEA, 2005). *Provisioning services* are products or materials directly generated from ecosystems (Guo et al., 2001; Egoh et al., 2012); it incorporates crop goods, fruits, medicinal plants, fish, fiber, timber, wool, water, gene, etc., (MEA, 2005b; Hawkins, 2003; Hopkin et al., 2011). *Supporting services* represent processes that support the supply of all other services of nature; thus, provision of habitat, soil formation, photosynthesis, nutrient cycling and water cycle are categorized as *supportive services* (Heathwaite et al., 2012). *Regulatory services* are the benefits derived from the "natural regulation of ecosystem" functions (Schroth and

McNeely, 2011); it consists of regulation of climate and air quality, water regulation (that is runoff and flood), erosion control, pollination, purification (detoxification) of water, etc., (MEA, 2005; Egoh et al., 2012). *Cultural services* refer to the use of ecosystems for ecotourism, aesthetics (like art and architecture), recreation, heritage, rituals and spiritual worship (Schroth and McNeely, 2011; Egoh et al., 2012).

*Dynamics of Ecosystem Service Value* (ESV) indicates the change in the values of goods and services obtained from nature in response to changes in LULC overtime (Kreuter et al., 2001; Tian-hong et al., 2010; Costanza et al., 2014).“Land use” is the purpose for which people exploit land and its resources; “land cover,” however, is the biophysical state of land (Briassoulis, 2000). LULC change refers to the modification or conversion of a LULC class into another one in a locality (Turner *et al*., 2000). Where LULC classes undergo change, the resultant becomes tradeoffs (that is, gains and losses of ESV) (Balmford et al., 2011; Elmqvist et al., 2011); the implication is that a rise in one service may lead to loss/decrease in another; but, the service value may decrease, increase or remain unchanged (Yuan-wang et al., 2006; Yun-guo et al., 2011) depending on the “value coefficient” allocated for the LULC classes among which the alteration takes place (Costanza et al., 1997). There would be, for instance, no change (gain/loss) in ESV if the change occurs between LULC classes having equivalent service value (Kreuter et al., 2001; Li et al., 2007; Chanhda et al., 2009). In fact, an ecosystem service change could be a replacement (if not always) of a set of services by another set of goods/services due to LULC dynamics so that its value changes too (Yuan-wang et al., 2006; Kindu et al., 2016). Conversion of a forest into crop farming implies increase in the supply of cropland services (like production, pollination and/or biological control) (Costanza et al., 1997) at the cost of forest services such as fuel and timber products, medicinal values, climate and gas regulation, erosion control, habitat provision, biodiversity, etc., (Myers, 1997a; Bishop, 1999; Moore et al., 2011). This affects temperature, rainfall and hydrology of the area where LULC change occurs (MEA, 2003; MEA, 2005).

The occurrence of LULC dynamics and the subsequent change of ecological service take place through three vital processes (models) (McNeill et al., 1994): *harvest* is the exploitation of goods and services from nature (through hunting, gathering, grazing, fuel-wood and timber cutting, etc.,); the effect of these actions is modification of environmental resources/LULC; *replacement* refers to the transformation from a certain category of ecological/LULC class to another (through processes such as, clearing, tilling, draining, construction, etc.); and, *transfer* represents processes involving application of additional

resources/inputs to improve or intensify production such as use of fertilizer, improved seeds, herbicides, pesticides, … (McNeill et al., 1994). These land transformation processes are collectively referred to as the *proximate sources of change* - actions that directly contribute to the changed state of LULC classes or environmental resources (Turner II and Meyer, 1994).

*Change drivers* refer to natural and socio-economic variables that cause changes in ecological services (MEA, 2003), sometimes, by facilitating LULC dynamics (Newcome et al., 2005; Kindu et al., 2016). Change drivers could be direct and indirect causes (MEA, 2003; De-Groot et al., 2010; Heathwaite et al., 2012). *Direct drivers* could, specifically, be (De-Groot et al., 2010): *positive drivers* – are causes or actions that bring positive changes or improvements in ESV of nature, like conservation actions (area closure), ecotourism, organic farming, etc.; *negative drivers* – represent actions that cause adverse effects on natural resources such as habitat destruction, pollution, overuse of resources, etc.; and, *neutral drivers* – refer to actions having positive or negative effects on resources depending on circumstances where the actions operate, such as LULC change (De-Groot et al., 2010). *Indirect drivers*, also known as *root causes*, are natural and socio-economic variables that indirectly cause ecological changes by proximately influencing direct drivers (MEA, 2003; Heathwaite et al., 2012). Growing human population (Belay, 2002; MEA, 2003), progresses in science and technological innovations, weakening of cultural diversity, loss of indigenous knowledge, etc., are major root or indirect causes of LULC dynamics and the changes in the service values of nature (MEA, 2005; Newcome et al., 2005; Shackleton et al., 2008; De-Groot et al., 2010; Heathwaite et al., 2012).

*An agro (cropland) ecosystem* is a set of farm-plots (land) exploited for the production of various goods and services such as "food, feed, fiber, oil seeds," etc., (Brady, 2007). Several cropland-related studies were targeted on assessment of either the services or disservices, or both; that is, the various products it offers for people, the ecosystem services upon which it depends (Antle and Capalbo, 2002; Sandhu *et al.*, 2008; Power, 2010; Foley et al., 2011), and the adverse effects (or disservices) to and from it were points of emphasis by many studies about agricultural landscapes (Zhang et al., 2007; Swinton et al., 2007; Norris et al., 2010; Garbach et al., 2014).

Agro-ecosystems provide various direct and indirect services to people and the environment (Swinton, 2007; Norris et al., 2010; Gomez-Baggethun and De-Groot, 2010) (see the top-right box in Figure 2.1). Cropland ecosystems provide "on-farm" and "off-farm" services (Zhang et al., 2007; Garbach et al., 2014). Provisioning products like food, fiber, biofuel, materials with medicinal values, etc., are direct

(consumptive) services generated from agricultural systems (Antle and Capalbo, 2002; Scott et al., 2006; Sandhu *et al.*, 2008; Porter *et al.*, 2009; Foley et al., 2011), and these services are largely "on-farm" benefits of croplands (Zhang et al., 2007). Supportive (like habitat provision for pollinators), regulatory (like control of micro-climate via carbon sink, soil conservation, etc.,) (Norris et al., 2010; Sthapit and Scherr, 2012; Robertson et al., 2014), and cultural services are other "on-farm" benefits of croplands where agro-forestry is dominantly practiced by farmers (Swinton, 2007; Norris et al., 2010; Schroth and McNeely, 2011). Agro-ecosystems also offer "off-farm" benefits, which refer to products supplied to markets (Garbach et al., 2014).

Ecosystem services of nature and the management practices of farmers determine the diversity and amount of services offered by agro-ecosystems (Tscharntke et al. 2005; Sthapit and Scherr, 2012). Supply of genetic materials (Matson et al., 1997), regulation of water amount and quality, biological pest control, pollination, improved soil structure, enriched soil fertility status, etc., are among the services upon which productivity of cropland depends (Antle and Capalbo, 2002; Sandhu *et al.*, 2008; Norris et al., 2010; Foley et al., 2011) (see the top-left box in Figure 2.2). Farm households, through application of diverse inputs (such as fertilizer, improved seeds, labor, etc.,) and other practices, impact the level of services generated from croplands (Matson et al., 1997; Garbach et al., 2014); meaning, better management practices ease and enhance the sustainable flow of services (say food, fiber, etc.,) from agro-ecosystems (Tscharntke et al., 2005; Power, 2010); however, poor management of croplands (like inappropriate tillage, poor/little conservation practice, limited crop rotation, etc.,) retards the extent of services flow from such systems (Swinton et al., 2007).

Croplands adversely influence the service flow from agricultural landscapes (meaning, disservices from agro-ecosystems) (see the bottom right box in Figure 2.2). "Disservices" refer to the adverse effects from cropland systems (Zhang et al., 2007). That is, disservices are usually the unintentional consequences of management actions (by farmers) on agricultural landscapes (Garbach et al., 2014). Agricultural expansion (into forest, shrub-land and grazing-land) leads to soil (land) degradation, loss of biodiversity and destruction of habitat (Swinton et al., 2007; Maeda et al., 2010; Foley et al., 2011). Croplands also lead to undesirable effects or changes in the process and structure of ecosystems through "intensification" of farming (Smith, et al., 1999; Dale and Polasky, 2007; Reeling and Gramig, 2012); that is, intensive use of chemical fertilizers on croplands leads to eutrophication (excess nutrients, nitrogen and phosphorous, concentration in soils and water bodies) (Collard and Zammit, 2006; Dale and Polasky,

2007; Reeling and Gramig, 2012); and, pollution of air, terrestrial and aquatic ecosystems is a resultant of eutrophication (Matson et al., 1997; Swinton et al., 2007; Norris et al., 2010). That is, dense growth of algae (that kills other photosynthetic plants by restricting sunlight entry into the water floor) and depletion of organisms (like zooplankton, fish, etc., aquatic resources) are adverse effects of eutrophication (Smith, et al., 1999; Zhang et al., 2007; Butler et al., 2007). Use of genetically modified seeds/seedlings results in reduced crop biodiversity (Matson et al., 1997).

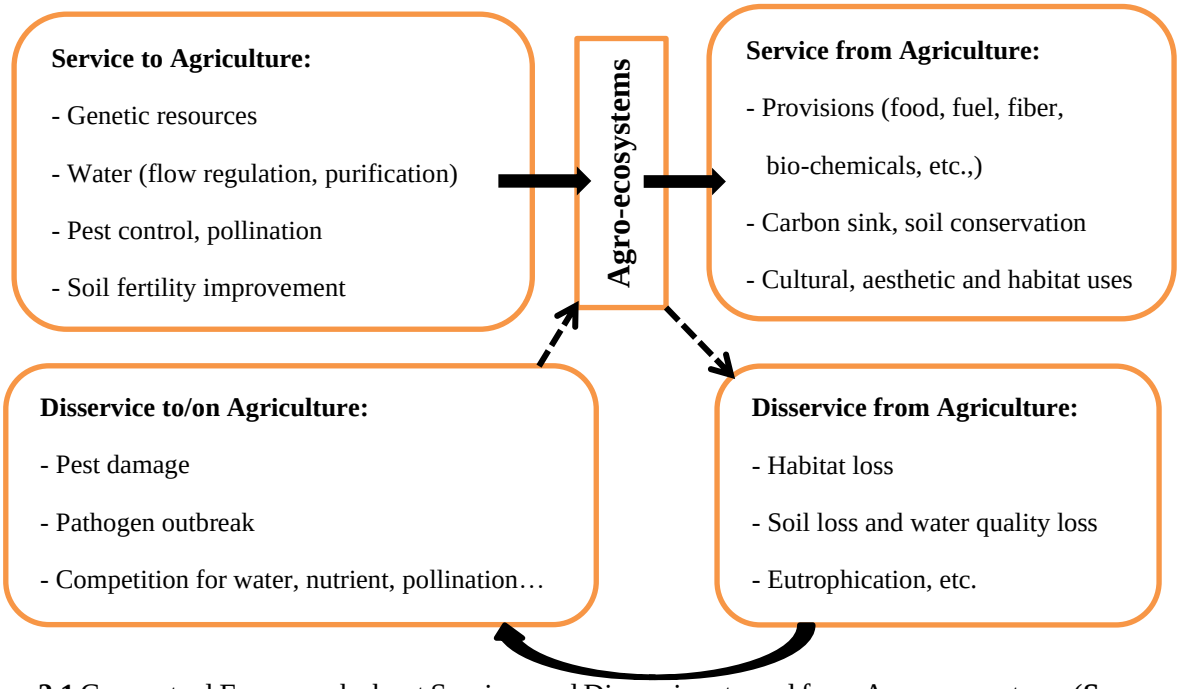


**Figure 2.1** Conceptual Framework about Services and Disservices to and from Agro-ecosystems (**Source**: Adapted from Zhang et al., 2007; Swinton et al., 2007; and, Garbach et al., 2014).

Ecosystem service flow from agro-ecosystems can also be negatively impacted by constraints originating from sources outside agricultural systems (that is, disservices to agriculture) (bottom left box in Figure 2.1). Meaning, services of croplands could be damaged by invasive pests and sudden outbreak of pathogens (like bacteria, virus, etc.,) that may cause disease (Swinton et al., 2007; Power 2010). Limitations in environmental services such as deficiency in nutrient availability, scarcity in moisture supply and inadequate availability of biotic pollinators also restrict amount of service flow from croplands (Zhang et al., 2007; Schroth and McNeely, 2011); in other words, this is observed where there is a high competition for nutrient, moisture and pollination services essential for the production of goods from agricultural landscapes (Foley et al., 2011; Garbach et al., 2014).

It should be underlined that the interest, in this study, is not to address all the services and disservice to and from cropland ecosystems (Figure 2.1). The focus, rather, is largely on the direct provisioning (consumptive) services generated by smallholder farmers from croplands of HRC, Southern Ethiopia (see the top-right box in Figure 2.1). This is so because, quantifying economic value of consumptive cropland products (Bishop, 1999) of the Catchment (through anthropocentric perspective) is among the principal targets of the study.

Values and valuation techniques are also among the key concepts used in this research work. The term *value* can be defined as the contribution of an attribute (action) to the realization of a particular purpose or condition (Coztanza et al., 2006). Normally, people's value to environmental resources (or services) is highly influenced by individuals' value systems (Farber et al, 2002). So, *value systems* are outlines of moral rules and standards individuals use to allocate significance or weight on goods and services to their beliefs/actions (Farber et al, 2002; Coztanza et al., 2006).

*Valuation*, on the other hand, is the way of measuring the role (benefit) of a certain attribute, service or event that satisfies a specific target (Freeman, 2003). So, *valuation* of environmental services refers to the procedure of allocating or assigning values for the diverse benefits of nature (Coztanza et al., 2006; Brown et al., 2007; Turner et al., 2008). Values of environmental services are measured upon prices as prices are simple to understand and readily available, and they also provide a rational or realistic reflection of individual's choice on goods (Moore et al., 2011; Boyd, 2012).

Values of environmental services could be *use values* and *non-use values* (Freeman, 2003; Watson, 2007; Brown et al., 2007). *Use values* refer to values of benefits acquired through physical interaction with certain attributes of ecology. Use value, again, can be *direct* and *indirect* use values. *Direct use values* are values of goods and services that are directly utilized by people (here, it has to be recognized that the utilization can be in the form of sale or consumption of a product of nature, say timber, fish, tour value, etc.,) (Hawkins, 2003;). Again, *direct use* value can be *consumptive* use value and *non-consumptive* use value (Brown et al., 2007); *consumptive use value* represents the use value of products exploited from nature such as food crops, potable water, fruits, fire-wood, charcoal, biomass (pasture), medicinal plants, etc.; *non-consumptive use value* refers to the use value of benefits obtained without exploiting anyone environmental component like tour value, recreation value, increased living comfort, value for education purpose, etc., (Brown et al., 2007).

*Indirect use values* refer to values of ecosystem attributes/services that support products of nature which are directly consumed by people (Watson, 2007; Brown et al., 2007); in other words, indirect use values represent values of ecosystem attributes (or functions) which are not directly used by human beings. Regulation of climate and water, nutrient cycling, pollination, soil provision and retention, erosion control, purification of water, flood control, storm prevention, carbon sequestration, etc., are examples of indirect use values (Hawkins, 2003; Brown et al., 2007).

*Non-use values* represent values of ecosystem attributes which do not require physical interaction by people (Hawkins, 2003). *Non-use value*, according to Watson (2007), is defined as "value of the continuation of the provision of a good or service even where an individual has no intention of using the resource." Non-use value can be *existence, altruism,* and *bequest* values (Watson, 2007). *Existence value* is value of the satisfaction obtained from recognizing the existence of a natural resource in an ecosystem; it indicates the "moral" reasons for protecting environmental resources(Freeman, 2003); that is, a value which is not associated with any current or future use; rather, it is a value related to the knowledge of continued existence of species, habitats and ecosystems (Edwards and Abivardi, 1998; Freeman, 2003). *Altruistic (altruism) value* refers to values of ecosystem benefits which are supposed to be used by other people of the current generation; in other words, it indicates a value attached by people to the fact that other people of the present generation have access to the benefits given by environmental resources; hence, it can be expressed as an intra-generational equity concern; but, *bequest value* indicates the availability of environmental resources which are going to be used by future generations (Edwards and Abivardi, 1998; Brown et al., 2007); it reflects peoples' willingness to pay for the sustenance of benefits so that the resources shall be enjoyed by the future generations; thus, this value represents the publics' willingness to pay for the conservation of existing species of flora and fauna, habitats, and overall ecological systems as well as the willingness to pay for curving changes thought to be irreversible like species extinction (Freeman, 2003; Brown et al., 2007).

V*aluation technique (model)* is another vital concept in this research work. A *valuation technique (model)* is a method or procedure via which values of environmental services can be measured (Turner et al., 2008; Moore et al., 2011). In this regard, Costanza et al. (1997) developed a widely acknowledged general model, which was primarily aimed at estimating the value of environmental services of the world; meaning, "valuation coefficients" were assigned (in US$/ha/year) for the services and goods derived from the varying biome categories worldwide. Even if most of the assigned values were different from

market prices, the model allocated "value coefficients" of seventeen ecosystem services for sixteen biomes globally (Costanza et al., 1997). "Value coefficients" of Costanza et al. (1997) could also be used for district or local level studies for quantifying the gains and losses of ESV that could be brought by dynamics in LULC (Kreuter et al., 2001; Li et al., 2007; Chanhda et al., 2009; Kindu et al., 2016); this can be done with application of a standard economic "sensitivity analysis" (Pannell, 2013). "Sensitivity analysis" is used for controlling accuracy of service value changes estimated upon existing and/or modified value coefficients of the global scale biome classes by local level studies; that is, it is used for accepting or rejecting results of the computed ESV changes by local studies (Luan-wang et al., 2006; Kindu et al., 2016). Measuring LULC dynamics-induced net gains and losses of ESV is best done with application of "change matrix data" obtained through GIS-based change detection (Yun-guo et al., 2011).

Measuring current values of environmental services could be done using methods of the "cost-side" and "demand-side" approaches (Haines-Young and Potschin, 2009). Studies conducted upon the *cost-side* approach may use the following specific valuation methods: *replacement cost method* – is a method that involves estimating the cost required to supplant ecosystem services through man-made measures (De-Groot et al., 2002; Brown et al., 2007; Turner et al., 2008; Moore et al., 2011); it can be done upon the price of the lowest-cost alternative way of getting a particular service (Haines-Young and Potschin, 2009); for instance, a wetland's value treating contaminated (waste) water could be quantified upon the cost of chemical or physical options used to purify the water (Coztanza et al., 2006); *restoration cost technique* – is a method involving to quantify the cost required to restore ecosystem benefits to their original conditions (Moore et al., 2011); *relocation cost method* – is a technique of estimating the cost of relocating natural properties like habitats; in this case, cost required to transfer a habitat to an alternative location, for example, can be considered as values of the same habitat (De-Groot et al., 2002; Qenani-Petrela et al., 2007); and *avoidance cost method* – involves estimating the damage overcome (avoided) as a result of a service given by an ecosystem (Turner et al., 2008; Haines-Young and Potschin, 2009). Anyway, values estimated using methods of the cost-side approach do not mirror strict measure of utilities derived from nature, and hence, analysis made upon methods of this approach is not reliable for policy suggestions (Brown et al., 2007).

Valuation studies made upon the *demand-side* approach apply *revealed preference* and *stated preference* techniques for quantifying largely non-marketed services of nature (Freeman, 2003; Madureira et al., 2007; Qenani-Petrela et al., 2007; Polasky, 2008; Moore et al., 2011). *Revealed preference* method

involves using "travelling and access costs people are willing to pay to use an ecosystem for recreational purposes" (Hawkins, 2003); it is used for estimating only "use values" and experienced scenarios (Qenani-Petrela et al., 2007;Haines-Young and Potschin, 2009). This method considers existing markets even if it does not depend on direct market values; and hence, it is assumed to be more acceptable for policy makers than the *stated preference* technique(Haines-Young and Potschin, 2009; Moore et al., 2011). Revealed preference technique involves applying "travel cost" and "hedonic pricing" methods for valuing environmental services (OECD, 2002; Coztanza et al., 2006; Brown et al., 2007; Freeman et al., 2014): *Travel cost* method applies survey data on direct costs posed to gain a benefit (Watson, 2007); it involves estimating the price for visiting a tour site based on the cost required to travel to that particular site; here, the idea is that the cost, people are willing to pay for traveling to a tour area, should, at least, be the minimum service (visiting) value of the area (Brown et al., 2007; Qenani-Petrela et al., 2007). *Hedonic pricing* - involves estimating implicit price for natural entities through people's choice for market goods that consider such entities; that is, measuring implicit price of air quality could be possible within the value/price of a house for sale or rent (MEA, 2003; Brown et al., 2007; Freeman et al., 2014).

The "*market value (direct)*" *technique* can be considered as one of the methods of the *demand-side* approach since it directly measures people's willingness to pay, and as market values also reflect strict measure of utilities of services (Hawkins, 2003; Boyd, 2012). Besides, it is indicated that this technique is a kind of revealed preference method (Hawkins, 2003) even if it was categorized as a separate method from the "revealed preference technique" in some literatures (OECD, 2002; Watson, 2007). *Market value/price method* is different from other methods of the demand-side approach in that it is applied to estimate product values of nature exchanged in formal markets (such as crops, fish, timber, firewood, bio-chemicals, etc.,) (De-Groot et al., 2002; Freeman, 2003); however, it has some drawbacks since prices may be influenced by subsides (that is prices may not reflect exact monetary or market value of products where governments subsidize farmers and/or other resource users) (OECD, 2002; Hawkins, 2003); moreover, the market price technique is useful to quantity the economic values of only selected goods as most environmental services are not supplied to formal markets and, hence, have no values that are measured in prices (OECD, 2002; Coztanza et al., 2006; Moore et al., 2011).

*Stated preference* method involves applying hypothetical questions to recognize peoples' willingness to pay for environmental services and to determine values of the services (Freeman, 2003; Madureira et al., 2007; La-Fuente et al., 2010;Bamlaku, 2014). Unlike revealed preference, this method can be applied to

measure "non-use" values and circumstances that are not experienced (Turner et al., 2008; Haines-Young and Potschin, 2009). "Stated preference" method consists of two specific methods: the first is *contingency valuation* - which involves organizing hypothetical markets where people are requested to express their willingness to pay for numerical or qualitative changes in ecosystem services (Carson et al., 2001; Madureira et al., 2007; La-Fuente et al., 2010; Freeman et al., 2014); its weakness is that values stated by participants of hypothetical market may not reflect actual prices individuals are willing to pay (Carson et al., 2001; Brown et al., 2007). The second is *choice modeling (experiment)* – requires organizing hypothetical markets so that people are allowed to choose their most preference from a set consisting of "more than two choice options," which are referred to as "attribute bundles where the price is included" (Qenani-Petrela et al., 2007). In this method, individuals are made to face with two or more options with shared attributes of the services to be valued, but with different levels of attribute (that is, one of the attributes being the money individuals are assumed to pay for the service) (Qenani-Petrela et al., 2007; Polasky, 2008).

Applying anyone of the valuation techniques, described above, depends on the kind of service to be measured (Hawkins, 2003), and also on the availability, adequacy and accuracy of data for the study (Freman, 2003). Where the target is quantifying provisioning services, the *market value (price)* method is credibly appropriate (De-Groot et al., 2002; Freeman, 2003; Boyd, 2012). Economic value of services derived from an ecological setting functioning naturally could be quantified with application of the *replacement cost* technique (Coztanza et al., 2006). Generally, regulation services such as regulation of gases, water, climate, etc., are most often valued using *replacement cost*, *restoration cost*, and/or *avoidance cost* techniques (Farber et al., 2002; Madureira et al., 2007; Haines-Young and Potschin, 2009). For quantifying the tour and recreational values of any environmental resource or site, the *travel cost* method is appropriate. *Contingent valuation* survey is applied where there is no real ecological use to measure the value of services assumed to be less tangible, say for instance, the economic value of threatened wildlife habitat (Coztanza et al., 2006; Haines-Young and Potschin, 2009 La-Fuente et al., 2010). For other non-marketed services, other methods of the "demand-side" approach are relevant.

On the other hand, in cases where application of any of the methods of the *cost-side* and *demand-side* approaches is difficult, *value (benefit) transfer* approach is an alternative technique of quantifying the values of environmental services (Wilson and Hoehn, 2006; Costanza et al., 2006; Plummer, 2009). A *value (benefit) transfer* is a technique that "involves obtaining an estimate for the value of ecosystem

services through the analysis of a single study, or group of studies, that have been previously carried out to value 'similar' goods or services in 'similar' locations" (Costanza et al., 2006). Meaning, this technique is applicable to measure values of similar benefits that can be acquired from areas with similar biophysical environment (Qenani-Petrela et al., 2007; Plummer, 2009; Freeman et al., 2014). It is thought to be significant for estimating non-marketed ecosystem benefits (Qenani-Petrela et al., 2007; Freeman et al., 2014), and where valuation studies are highly constrained by time and financial resources (Costanza et al., 2006).

### 2.1.2 Theoretical Framework

Reviewing the overall research philosophy and the theoretical views about the problem (ecosystem services) studied is of great worth as it is valuable for identifying the view by which the study is governed. That is, philosophical and/or theoretical views mirror the type of research approaches to follow, the kinds of problems to investigate (or services to measure), the specific methods of data collection and analyses to be applied (Callicott, 2004; Creswell, 2009), etc.

Social and environmental-related studies could be governed by philosophies such as positivist or post-positivist, constructivist, pragmatist, etc., views (Corbetta, 2003; Creswell, 2009). *Post-positivist* view assumes that effects are determined probably by causes, requires careful observation and measurement of objective realities and developing numerical measure of observations, involves testing and verifying theories governing the world (deduction), etc. *Constructivist view* requires understanding the world where people live, developing subjective meanings of realities, exploring new facts and ideas upon participants' view, generating theories (induction), etc. *Pragmatist view* assumes applying divergent strategies (from post-positivism and constructivism) to better address the problem studied. Applying either of these and other philosophies depends on the problems studied. That is, where the research interest is to begin from a theory, the philosophy becomes "post-positivism" and the approach would be quantitative. The philosophy is most likely the "constructivist" view and the approach becomes qualitative where the issue studied is often new; where the research is targeted largely on tackling a problem, "pragmatism" is most appropriate and mixed-methods become its relevant research approach (Corbetta, 2003; Creswell, 2009).

On the other hand, the valuing concept of ecosystem services has led to the origin of different theories. As a matter of fact, environmental services have *instrumental* and *intrinsic* values (Hawkins, 2003; MEA, 2003; Callicott, 2004; Coztanza et al., 2006). *Instrumental* value indicates the value of an attribute to the

welfare of another entity in an ecological setting; here, timber and charcoal benefits for human beings are *instrumental* values of a forest ecosystem (Hawkins, 2003; Goulder and Kennedy, 1997). An *intrinsic* value is the value of a natural entity in itself or for its own existence (Hawkins, 2003; Coztanza et al., 2006). A worry about "intrinsic" value of a forest resource in an ecological setting, for instance, is a claim about the survival right and sustenance of the forest in the setting (Coztanza et al., 2006). In connection with *instrumental* and *intrinsic* values of resources, there are three categories of perspectives in environmental philosophy: *anthropocentric*, *eco-centric*, and *bio-centric* theoretical views (Goulder and Kennedy, 1997; Hawkins, 2003).

The *anthropocentric* view claims that only people have intrinsic values and other components of ecosystems are instrumental to the success of people's targets (Hawkins, 2003; Callicott, 2004). In this theoretical lens, services of other living and non-living components of nature are valued economically from the perspective of satisfying the livelihood needs of human beings(MEA, 2003). But, this does not mean that ecosystems have no values in their inherent conditions (Goulder and Kennedy 1997; Hawkins, 2003). Even if the anthropocentric lens is limited to value nature from the viewpoint of human benefits, this value may also incorporate people's choices associated with the welfare of flora, fauna, and others (MEA, 2003). Thus, valuation studies conducted through the anthropocentric lens tend to measure the *instrumental* values of ecosystem services from the viewpoint of utilities to people (MEA, 2003); this is so because, economic valuation is, at least theoretically, possible only for instrumental values (Brown et al., 1993).

According to the *eco-centric* lens, "ecosystem processes have intrinsic value while individual species have instrumental value" (Hawkins, 2003). Meaning, in this philosophy, *ecosystem processes or functions*, which are the ultimate sources of ecosystem services and goods (MEA, 2005), are assumed to have intrinsic values; whereas, organisms (plants and animals) are viewed to be supportive (instrumental to) the smooth operation of ecosystem functions in a setting (Hawkins, 2003; Callicott, 2004). So, the tendency to focus on the intrinsic values of environmental processes or overall balance of ecological systems, for investigation, is an eco-centric view (Callicott, 2004).

The *bio-centric* view is concerned with the fact that biotic components of ecosystems have intrinsic values and abiotic entities have instrumental values (Meffe and Caroll, 1997; Hawkins, 2003). The non-living environmental attributes have *instrumental* values imply that they support the sustenance of biological entities in a setting (Goulder and Kennedy, 1997). In this theory, abiotic materials like soil

nutrient, moisture, sun-light, etc., supporting the sustenance of green plants (MEA, 2005) are viewed to have instrumental values. Here, a principal concern about the sustainability right (or *intrinsic* value) of the diverse plants and animals is purely a bio-centric view (Coztanza et al., 2006). Meaning, a primary worry about the existence of endangered animal species in a certain locality is a bio-centric perspective; however, a concern about the tour value of the same animal becomes anthropocentric rather than a bio-centric view (Callicott, 2004; Coztanza et al., 2006); this is so because, tour value of animals is an instrumental, meaning, a benefit for people.

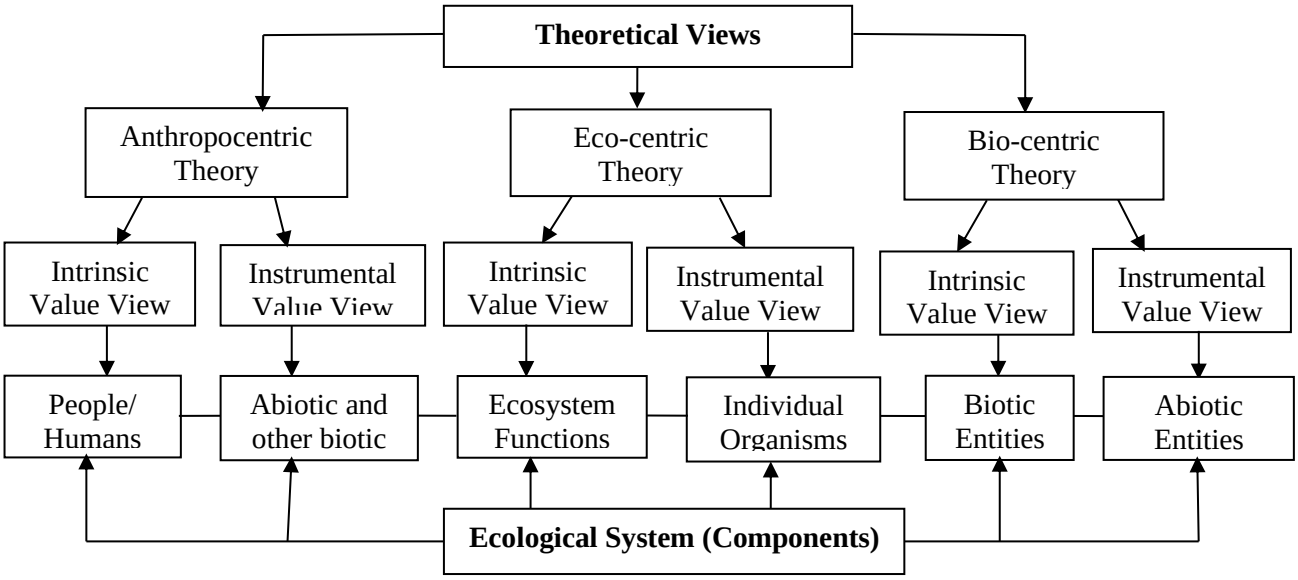


Figure 2.2 Theoretical Framework about Values of Ecosystems [**Source:** own design (2017) upon literature from MEA, 2003; Hawkins, 2003; Callicott, 2004; MEA, 2005; Costanza et al., 2006].

It is desirable to underline that the utilitarian (instrumental) values, economists are referring to, could, theoretically, be measured financially even if intrinsic values could not (Brown et al., 1993). The economic approach to the estimation of environmental services, therefore, is an *anthropocentric* view upon the utilitarian principle (Brown et al., 1993; MEA, 2003; Callicott, 2004). It should be clear that *anthropocentric utilitarianism* does not essentially mean that ecosystems have to be exploited intensively without care; and, it does not also mean that they, as natural entities, have no values (Goulder and Kennedy, 1997). Thus, where the target is assessing the benefits ecosystems provide to humans, the sole theoretical basis of valuing ecosystem services becomes the anthropocentric view (MEA, 2003; Hawkins, 2003).

Figure 2.2 above illustrates about how scholars with different theoretical lenses (such as anthropocentric, eco-centric and bio-centric) view values of the various components of ecosystems and their goods and services. For instance, an ecosystem element/component, which is considered as "intrinsic" in one philosophical view, may not be "intrinsic" (or may be "instrumental") in another theoretical view (see Figure 2.2). It should be noticed that the attributes displayed in the boxes immediately above the bottom layer (box) are the components/attributes of an ecosystem; and the six boxes containing the elements (people, abiotic, biotic, etc.,) are connected by lines without arrows just to indicate that they are mutually linked to each other in an ecological setting (in terms of material acquisition, energy flow, etc.), and also each is a subset of the system (MEA, 2005).

## 2.2 Review of Related Empirical Literature

Even if measuring ecological service values is a relatively recent agendum, it is known that numerous studies have already been conducted about the dynamics and change drivers of ESV, impacts of ESV changes/losses, and current service values of ecosystems (cropland, forest, woodland, etc.,) world-wide. Hereafter, a review is made upon empirical evidences of studies made about these issues.

Environmental services undergo change due to unsustainable use of resources by human beings and the dynamics nature of earth (MEA, 2005a). Over three-fifth of the global ecosystem services had already been depleted (MEA, 2005). That is, provisioning (fish, firewood, charcoal, genetic resources, bio-chemicals, etc.), regulatory (control of air, climate, pest, erosion, etc.), and cultural (religious, spiritual, and aesthetic) services had been degraded within the second half of the $20^{th}$ C and the beginning of $21^{st}$ C (MEA, 2005a; WRI, 2008). Living organisms of inland water and species of wetlands went to extinction by 50%, and abundant habitat of wildlife had got depleted within 1970 – 1999 (WEHAB, 2002; WRI, 2008). Moreover, about three-fourth of the main marine fish resource, nearly one-fourth of the mammals, and over one-ninth of the birds had got depleted and/or threatened globally (WEHAB, 2002). Deforestation induced rate of loss of forest cover was 14.6 million ha/year within 1990 – 2000 worldwide (WEHAB, 2002). Soil erosion, compaction, and chemical pollution had also led to the critical degradation of two-fifth of the global agricultural land (MEA, 2003).

Value dynamics of ecological services takes place anywhere globally in response to LULC changes (Costanza et al., 2014). Normally, several studies were carried out about the magnitude and driving forces of LULC changes worldwide (Geist and Lambin, 2002; Belay, 2002; Wondamlak, 2002; Lambin et al.,

2003; Brondızio, 2005; Evans et al., 2005; Tucker and Southworth, 2005; Pandit et al., 2007; Hartemink, 2008; Khreast et al., 2008; Abate, 2011; Binyam, 2015; etc.,). However, studies which have measured the impact of LULC dynamics on the status of ESV were not as large as those that have quantified the magnitude and rate of LULC changes (Kreuter et al., 2001; Yuan-wang et al., 2006;Li et al., 2007; Chanhda et al., 2009; Tian-hong et al., 2010;Yon-guo et al., 2011; Costanza et al., 2014; Kindu et al, 2016). Since most studies (quantifying ESV changes) were conducted outside Africa and as valuation studies are still limited in Africa (Egoh et al., 2012), it is vague to understand the magnitude of ESV losses and gains triggered by LULC dynamics in many Sub-Saharan countries of Africa.

Measuring and understanding the extent of ESV changes is necessary since results of many studies revealed losses (instead of gains) in ESV of environmental resources overtime (Kreuter et al., 2001; Li et al., 2007; Yon-guo et al., 2011; Leh et al., 2013; Costanza et al., 2014; Kindu et al, 2016, etc.,). For instance, ESV of San Antonio area of Texas (USA) revealed a decline from US$ 21.94 to 21.16 million within 1976 – 1991, where total ESV of the area had declined by only 0.78 million US$ (that is 4%) within the sixteen-year duration (Kreuter et al., 2001); and, increasing woodland at the cost of range-land contributed to the reduced level of ESV loss in San Antonio District (Ibid). ESV of Pingbian Miao area, in rural china, showed continuous decline from US$ 124.5 to 100.4 million within 1973 – 2004 (Li et al., 2007).The continuous dwindling ESV of the area within 1973 – 2004 was largely due to the transformation of forests and grasslands into shrub-land and cropland, respectively, and also as a result of the enormous decrease in ESV of mixed forest cover (by US$ 26.7million) (Li et al., 2007). Similarly, the Changsha area, central China, experienced a decline in total ESV from US$ 1,009.28 to 938.11 million within 1986 – 2000, where the total ESV of the area had revealed a loss by US$ 71.17 million (7.1%) in one and half decade (Yon-guo et al., 2011); and, this was due to expansion of cropland at the cost of woodland and water body, and rising extent of construction land in the area (Yon-guo et al., 2011). Decline of ESV was also observed in West Africa within 2000 – 2009 (Leh et al., 2013). ESV loss of the world in response to LULC dynamics in the period 1997 – 2011 was estimated at US$ 4.3 – 20.2 trillion within one and half decade (Costanza et al., 2014). Munessa–Shashemene area of Central-South Ethiopia had also revealed an estimated ESV decline by about US$ 19.3 - 45.9 million within 1973 – 2012 (Kindu et al., 2016).

It should be understood that LULC change-driven ESV changes may not always be negative (loss) (Kreuter et al., 2001; Chanhda et al., 2009). In this regard, an increase in the total ESV from US$ 21.94

to US$ 22.61 million (by 3% or US$ 0.67 million) was observed in response to LULC change in San Antonio area (USA) within 1976 – 1985 (Kreuter et al., 2001). Overall ESV of Luang Namtha Province of China also revealed growth by about US$ 6 million (that is, from US$ 682 to 688 million) within 1992 – 2002 (Chanhda et al., 2009); and, the rise in the ESV of the Province had largely emanated from the increase in the extent of "current forest," "permanent agriculture land," grassland, swamp and water LULC classes (Chanhda et al., 2009).

Magnitude of ESV change depends on the level of "valuation coefficient" assigned to each biome (LULC) category (Costanza et al., 1997). This means a high magnitude of change of a certain LULC class does not necessarily mean a large amount of ESV loss or gain from the same resource category, and the same is true for a LULC class with low magnitude of dynamics as it does not signify a low magnitude of ESV loss or gain from the same LULC category (Kreuter et al., 2001; Zou et al., 2005; Yuan-wang et al., 2006; Chanhda et al., 2009; Tian-hong et al., 2010; Yun-guo et al., 2011; Costanza et al., 2014; Kindu et al., 2016). In fact, amount of value coefficient of each ecological (LULC) class is a reflection of the diversity and amount of goods and services derived from each resource (LULC) category (Costanza et al., 1997).

As it can be seen from results of some studies, magnitudes of estimated ESV changes often tend to be larger or smaller (than the more appropriate calculated values) if estimations are carried out without application of the change matrix model (Kreuter et al., 2001; Yuan-wang et al., 2006; Li et al., 2007; Chanhda et al., 2009; Kindu et al, 2016). Estimation of a more appropriate (or true) value is possible using the "change matrix model," which is a procedure that enables computation of net ESV gains and losses in response to changes among different LULC classes overtime (Yon-guo et al., 2011); that is, magnitude of net ESV gains and losses of each ecological/LULC class is more accurately computed upon "area change matrix data," which are obtained through GIS-based change detection (Yon-guo et al., 2011). This has to be done as temporal changes of LULC classes result in tradeoffs between the diverse services derived from different categories of environmental resources (Balmford et al., 2011). Meaning, increase in one service implies decline in another.

Drivers of ESV dynamics vary across the world depending on circumstances where the change occurs (Heathwaite et al., 2012). Numerous studies revealed that dynamics of ecosystem services is triggered by farming expansion, firewood, charcoal and timber demand-induced deforestation (Belay, 2002; Geist and Lambin, 2002;Randolph et al., 2005; Abate, 2011; Binyam, 2015), climate variability, resource over-use,

over-grazing/browsing, poverty/low income (MEA, 2005; Kideghesho et al., 2006; Shackleton et al., 2008), government policy (Chanhda et al., 2009), infrastructure and settlement/urban expansion, invasion of exotic species, drought, chemical farm inputs, new technology (Pimentel et al., 2000; Geist and Lambin, 2002; MEA, 2003; Newcome et al., 2005; Egoh et al., 2012), etc.

The kind and degree of impact of proximate drivers of LULC and ESV changes certainly vary across regions, countries (developed versus developing), districts and, even, within a catchment (Imbernon, 1999; Newcome et al., 2005; Egoh et al., 2012). Use of innovative farming technologies (fertilizers, pesticides, etc.,), manufacturing (heavy metals, pharmaceuticals, etc.,), extraction of fossil-fuel and other minerals, urban expansion, climate variability and change, pollution, etc., (Newcome et al., 2005; Shackleton et al., 2008; De-Groot et al., 2010; Gerbersdorf et al., 2011; Heathwaite et al., 2012) resulted in considerable loss of ESV by destructing wetlands and grasslands, eliminating wildlife and dwindling biodiversity in developed nations (MEA, 2005; Newcome et al., 2005).

The drivers of ESV change in developing countries (Africa and others) are different to some extent from those of the developed world. Expropriation of communal land, infrastructure expansion (Tucker and Southworth, 2005), deforestation (for fuel-wood, timber, etc.,) (Randolph et al., 2005; Pandit et al., 2007), overuse and unwise use of natural resources, land conversion or farming and settlement expansion into ecological systems (Semwal et al., 2004; Hurni *et al*., 2005; Nautiyal and Kaechele, 2008; Mikias, 2014; Zewdie and Csaplovics, 2015), unemployment, land grab (or land lease for farm investment), poverty/low income, climate variability and change, introduction of alien species (Hurni, 2000; Shackleton et al., 2008; Egoh et al., 2012), limited conservation measures (Kidegheso et al., 2006), etc., are the main threats (drivers) of ESV changes underlain by rapid population growth (Belay, 2002; Egoh et al., 2012). Drivers like nature of land ownership, gov't policy, inadequate incentives (for the poor), shortage of reliable markets (for products of nature), commercial timber exploitation, privatization of communal resources (like rangeland), etc., have also facilitated ESV dynamics in different nations of Africa like Tanzania, South Africa, Mozambique, Botswana, Zimbabwe, etc., (Kidegheso et al., 2006; Shackleton et al., 2008). Assessing drivers of ESV changes is useful for setting interventions targeted to suppress adverse effects on ecological services and to promote the positive changes on the services (MEA, 2003).

LULC dynamics-induced change (or loss) of ecosystem service values adversely affects economic activities (agriculture) and environmental resources; that is, ecological service value loss impacts climate and hydrology of a locality (MEA, 2005a). Increasing trend and variability of temperature and rainfall,

catastrophic or extreme weather events (drought, hurricanes, flood, etc.,), change of climate, etc., are consequences of forest and woodland service value loss for gas regulation (carbon sink), flood regulation, soil erosion control and sediment retention services (Daily et al., 1997; Myers, 1997a; Moore et al., 2011). Loss of supportive and regulatory services of forest (due to LULC change or deforestation) also threatens the provision of water for home use and irrigation farming by catchments (MEA, 2003; Shackleton et al., 2008; Moore et al., 2011).

Nature provides provisioning, regulatory, supportive and cultural services (MEA, 2005); and values of these services (at global scale) were measured by Coztanza et al., (1997) and Alexander et al., (1998). Initially, total ESV of all biome classes of the world was estimated at US$ 33 trillion per annum, which was a bit less than two-fold of the GNP (US$18 trillion annually) of the globe, then (Coztanza et al., 1997). Since this figure (ESV) of the world had been criticized for over-exaggeration, it was (later) estimated to have been about 44 – 88% of the planet's GNP (Alexander et al., 1998).

Estimations were carried out about regulative services of nature by a number of studies at global and regional/country levels (Myers, 1997a; Sala and Paruelo, 1997; Naylor and Ehrlich, 1997; Daily et al., 1997; Östman et al., 2003; Losey and Vaughan, 2006). For example, the global cost of replacing nature's role in regulation of pests (which were threats of crop and livestock yield) was about US$54 billion annually (Naylor and Ehrlich, 1997). Tropical forests play significant role in maintaining air quality and regulating climate via carbon sink (MEA, 2005; Moore et al., 2011); thus, supplanting the annual carbon sink role of tropical forest was indicated to have required an estimated cost of US$ 3.7 trillion (Myers, 1997a), and that of grasslands was about US$ 200/ha/year worldwide (Sala and Paruelo, 1997). Adverse impact of soil erosion on primary production and environment is often critical, and from this angle, the on-site and off-site cost of soil erosion, in the USA, was about US$ 44 billion yearly (Daily et al., 1997). Native insects provide pest control services for crop farming, the value of which was US$4.49 billion in the whole USA per annum (Losey and Vaughan, 2006). "Average increase for inorganic and organic farmers due to presence of natural predators of an aphid species" was US$ 33/ha/year in Sweden (Östman et al., 2003).

A local scale or district level valuation of was also made about cultural, supportive, provisioning and/or regulative services by researchers in different parts of the world (Cameron et al., 1996; Myers, 1997b; Pimentel, 1998; Wilson and Carpenter, 1999; Guo et al., 2001; Costanza et al., 2006). Fresh water resources like streams and rivers provide tour, recreation and other services (MEA, 2005); in this regard,

recreation service value of water (of Columbia River) was found to worth US$ 16 – 125 per/person/month upon the travel cost method (Cameron et al., 1996; Wilson and Carpenter, 1999). Micro-organisms provide a support services by facilitating nutrient cycling (MEA, 2005); and, waste decomposing service value of micro-organisms was quantified at US$62 billion annually in USA (Pimentel, 1998). A forest ecosystem in Xingshan (China) was indicated to have been providing an annual value of US$ 70.24 million through tour, timber, other products, soil and water conservation, and gas regulation services (Guo et al., 2001). Provisioning services like bio-chemicals of forest can be used for direct medical treatment or as inputs for the production of medicines (Moore et al., 2011); and, from this perspective, value of plants for production of anti-cancer drugs was estimated at US$370 billion per year in USA (Myers, 1997b). The total ESV of wetlands, urban green space, marine ecosystem, forest, agricultural land, beaches and open fresh water of New Jersey district, USA, was estimated at US$19.4 million annually (Costanza et al., 2006).

Research works conducted about provisioning services of croplands and forest/woodland were numerous in developing nations (Appasamy, 1993; Metz, 1994; Emerton and Mfunda, 1999; Pimentel, and Wightman, 1999; Dovie et al., 2003; Vedeld et al., 2004; Sampson et al. 2005; Dovie et al., 2005; Watson, 2007; Nautiyal and Kaechele, 2008). However, studies which have quantified economic values of cropland products (Emerton and Mfunda, 1999; Dovie et al., 2003; Dovie et al., 2005; Watson, 2007; O'Farrell et al., 2011) and others were somewhat limited in Sub-Saharan countries of Africa (Reyers et al., 2009; Egoh et al., 2012). An estimated value of about US$ 679/HH/year was reported from crop yield in Serengeti area of Tanzania (Emerton and Mfunda, 1999). Value of irrigation-based crop harvest in an agro-pastoral rural village, South Africa, was measured at US$ 443 per/HH/year (Dovie et al., 2003). Annual income generated from livestock, crop harvest and woodland services in the same area (South Africa) was about US$ 1660/HH (Dovie et al., 2005; O'Farrell et al., 2011). Similarly, value of provisioning (consumptive) products of croplands in Bale area (Southeastern Ethiopia) was estimated at US$ 1157/HH/year (Watson, 2007). These valuation studies about cropland products were similar in that they did not show the per capita income (US$/person/year) obtained from crop harvest by inhabitants of the respective study areas (Emerton and Mfunda, 1999; Dovie et al., 2003; Dovie et al., 2005; Watson, 2007). In fact, it was indicated that investigating and mapping ecosystem services, in Africa, have been constrained, among others, by shortage of reliable data (Reyers et al., 2009; Egoh et al., 2012).

Different studies also attempted to quantify forest provisioning products used for energy consumption (like cooking, heating, etc.,), construction (that is, fence, home, other building, etc.,) food, medication and other purposes (Appasamy, 1993; Metz, 1994; Pimentel et al., 1997a; FAO, 2001; Pearce, 2001; Sampson et al. 2005; Watson, 2007; Nautiyal and Kaechele, 2008; Swanson and Chapin, 2009). More than half (55%) of the wood product globally is used for energy consumption (like cooking and heating) by two-fifth of the population worldwide (Sampson et al. 2005; Swanson and Chapin, 2009). Despite this fact, economic contribution of these services of forest/woodland is not well recognized at national and HH level, especially in developing nations (Sampson et al. 2005; Swanson and Chapin, 2009). For example, some studies revealed that, the estimated annual per/individual fuel-product consumption in selected developing nations was about 912 - 1,200 kg (Appasamy, 1993), 846 kg (Metz, 1994), 700 kg (Pimentel et al., 1997a), etc.; but these studies did not show the economic value and per capita earning of the fuel-products (Appasamy, 1993; Metz, 1994; Pimentel et al., 1997a).

Economic value of forest provisioning services were measured by some studies in Africa (Dovie et al., 2003; Vedeldet al., 2004; Dovie et al., 2005; Kideghesho et al., 2006; Watson, 2007). For instance, firewood service value for HH of Bale District (Ethiopia) was about US$ 165/HH/year (Watson, 2007); and, an estimated value of US$ 407 (per/HH/year) was earned from forest services (such as firewood, medicinal plants, honey, timber, forest coffee, etc.,) by HH of the same area (Watson, 2007). Income from more or less similar forest services of a district in South Africa was US$ 547.8/HH/year (Dovie et al., 2005). Charcoal was indicated to cost at US$ 10 - 14 per/HH/month in a study area in Tanzania; and, where value of this product was about US$ 120 – 168 per/HH annually (Kideghesho et al., 2006). But, these research works (Dovie et al., 2003; Vedeld et al., 2004; Dovie et al., 2005; Kideghesho et al., 2006; Watson, 2007) were common in the sense that they failed to indicate level of per capita earning from the forest/woodland products accounted in by the respective studies.

Studies that have measured LULC change-led ESV loss and current values of cropland and forest (woodland) services were limited in Ethiopia. LULC dynamics and its impacts were investigated by several researches made in different parts of Ethiopia (Solomon, 1994; Badege, 2001; Wondamlak, 2002; Hurni et al., 2005; Meles et al., 2008; Abate, 2011; Eleni et al., 2013; Hiywot, 2014; Mikias, 2014; Binyam, 2015, Zewdie and Csaplovics, 2015; etc.), including the study area, HRC (Abren, 2007; Yechale, 2012; Assefa and Bork, 2016); and, most studies revealed that LULC changes have resulted in dwindling supply of ecological services, especially in highlands where population pressure is high

(Wondamlak, 2002; Abate and Lemenih, 2014; Binyam, 2015). That is, increasing soil loss rate and depletion of nutrients (Lemenih et al., 2005; Binyam, 2015), declining land productivity (Zewdu et al., 2014), destruction of forest (Badege, 2001; Yechale, 2012), loss of natural habitat (Meles et al., 2008), decline of overall services of nature (Kindu et al., 2015), etc., were some of the adverse effects of LULC dynamics in Ethiopia. However, none of these studies (except Kindu et al., 2016) attempted to measure (economically) the amount of ESV loss in response to LULC changes in the country and the study area (HRC).

Research works, which have measured current values of cropland (Watson, 2007; Kindu et al., 2016) and forest services (Watson, 2007; Mamo et al., 2007; Babulo et al., 2009; Tesfaye et al., 2011) were limited in Ethiopia. Value of direct consumptive farm products (US$ 1157), in Bale Highlands, was quantified by Watson (2007); and, value of overall cropland services (food products, biological control and pollination) were measured at US$ 4.6 – 11.4 million in Munessa-Shashemene for 2012 (Central-South Ethiopia) by Kindu et al.,(2016). Role of forest products in income and/or food security status of households was assessed by Mamo et al., 2007 (in Central Ethiopia), Babulo et al., 2009 (in Tigray, Northern Ethiopia), and Watson, 2007 and Tesfaye et al., 2011 (in Bale area, Southeastern Ethiopia). Anyway, measuring net value of services through cropland and forest should be carried out from the viewpoint of earnings both at household (US$/HH) and individual (US$/person/year) levels, which, in fact, requires deducting the cost of inputs used for generating services from nature (cropland and forest) (Freeman, 2003; Hawkins, 2003). Results of such studies enable to understand the contribution of ecological services to the food security status of people in any locality (country).

## 2.3 Conceptual/Analytical Framework of the Dissertation

The target, here, is to demonstrate and clarify the concept map through which the dissertation work has been conducted. Figure 2.3 below illustrates the overall research philosophy and ecological worldview used to govern the dissertation work, the “themes” (like, ecosystems, current ESV, ESV changes, and its change drivers and impacts) assessed and the “methods/models” used for quantifying Current Provisioning Services (CPS) and ESV changes in HRC.

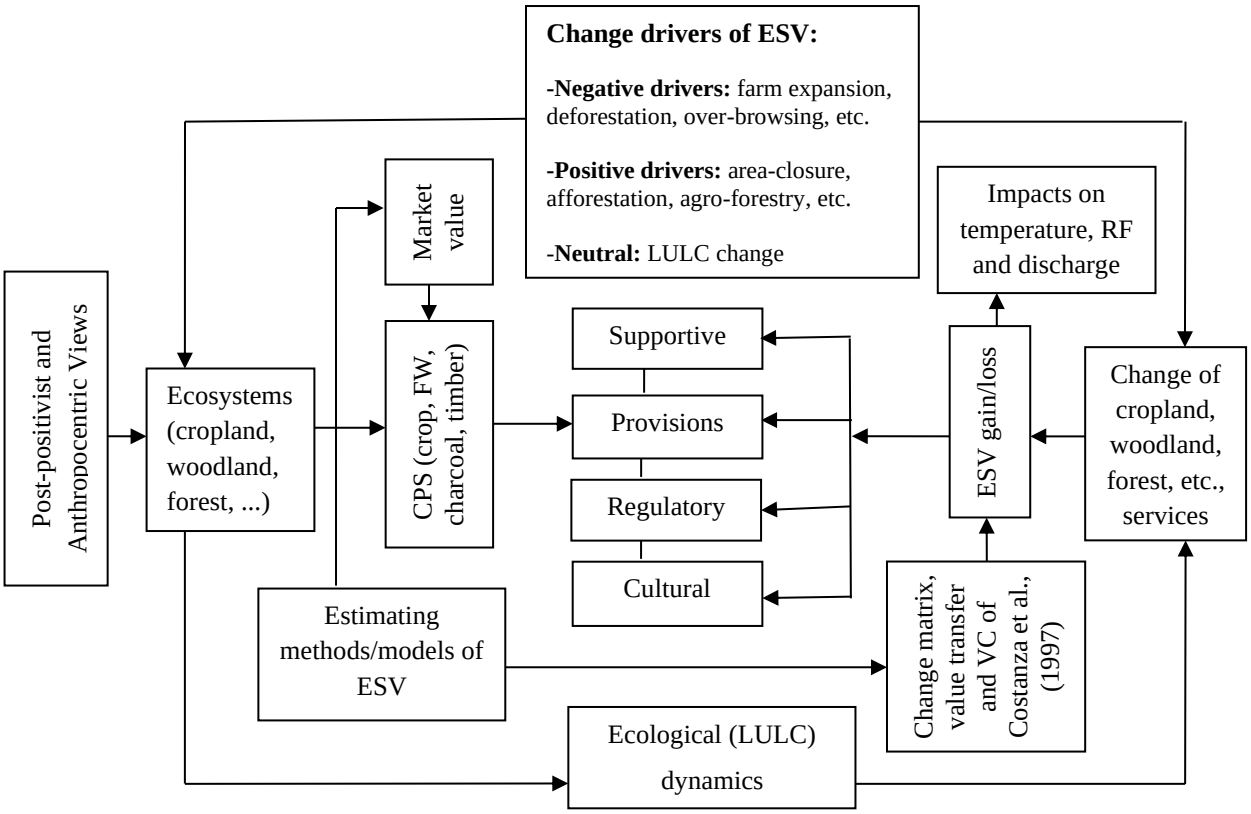


Figure 2.3: Conceptual/Analytical Framework about the Views, Ecosystem Services (ES), Drivers and Impacts of ES Dynamics, and Methods/Models Used for Estimating Values of Current Provisioning Services (CPS) and Overall ES Changes in HRC [**Source**: Own design (2017) upon Freeman, 2003; MEA, 2005; Nelson et al., 2009; De-Groot et al., 2010; Heathwaite et al., 2012]. [**Recall**: FW = Firewood; ESV = Ecosystem Service Value, VC = Valuation Coefficients]

The left-side middle box containing the phrase "post-positivist and anthropocentric" view is connected by an arrow with the immediate right-side box having the concept "ecosystems (cropland, woodland, forest, etc.,)" since this study was conducted upon the post-positivist philosophy and anthropocentric worldview of ecological services (Figure 2.3). The study, upon the anthropocentric lens, has measured the instrumental (instead of intrinsic) values of ecosystem services of HRC, financially, from the viewpoint of benefits for people (Freeman, 2003; Hawkins, 2003). With regard to the "themes," the "change drivers" (negative, positive and neutral) listed within the upper most box are linked by arrows to the left-side middle box consisting of "ecosystems" and also with the right-side middle box containing "change of cropland, woodland, forest, etc., services" just to indicate that these drivers cause changes in ecosystems and their services directly (Shackleton et al., 2008; De-Groot et al., 2010; Heathwaite et al., 2012). Again, in Figure 2.3, the phrase "ecosystems…" in the left-side middle box is connected by an

arrow with the right-side box containing "Current Provisioning Services (CPS) [crop, FW, charcoal and timber]," and this in turn is linked by another arrow to the immediate right-side (central) box containing "provisions;" this was done as the study was aimed at measuring the economic values of only these "provisioning" services of HRC.

All the four categories of ecological services are incorporated in the conceptual framework of the dissertation as it is illustrated in Figure 2.3 above; this is because, HRC provides all the four categories of ecological services (such as provisioning, regulatory, supportive and cultural services) (MEA, 2005; Table 4.6, Appendix II); and, hence, analysis of values of ES dynamics involved quantifying the gross and net value changes of all the four services of the study Catchment.

On the other hand, the inner bottom left-side box, consisting of "methods/models," is connected by an arrow to the upper, inner (left-side) box containing "market values" and to the middle, inner (left-side) box having "CES (crop, FW, charcoal and timber)" just to inform that market prices and costs were used for measuring values of these services of cropland and forest/woodland in HRC (MEA, 2005); and, the inner bottom left-side box, containing the term "methods/models," is also linked by another arrow to the inner bottom right-side box consisting of "change matrix, value transfer and VC of Costanza et al., (1997" and with "ESV gain/loss" to indicate that estimation of ESV gains and/or losses from cropland, woodland, forest, etc., services of HRC were carried out using models of change matrix, value transfer and VC of Costanza et al., (1997) (Kreuter et al., 2001; Freeman et al., 2014; Kindu et al., 2016). The right-side inner (middle) box containing "ESV gain/loss" is, again, linked by an arrow with the upper box consisting of "impacts on temperature, RF (rainfall) and Discharge" as the dissertation research was also targeted to analyze the impact of "ESV gain/loss" on temperature, rainfall, hydrology, etc., conditions of HRC, Southern Ethiopia (MEA, 2003) (see Figure 2.3).

# Chapter Three

# Study Area and Research Methodology

## 3.1 Description of Study Area (HRC)

### (a) Location, Topography and Drainage:

HRC is located within $6^0$02’13’’ – $6^0$17’55’’ N, and $37^0$27’09’’ – $37^0$37’51’’ E. It is found in Gamo-Goffa Zone, Southern Ethiopia. The Catchment has an area extent of 23,432.7ha. Its greater portion is within Gamo Highlands, and smaller part of it is situated within the Ethiopian Rift Valley.

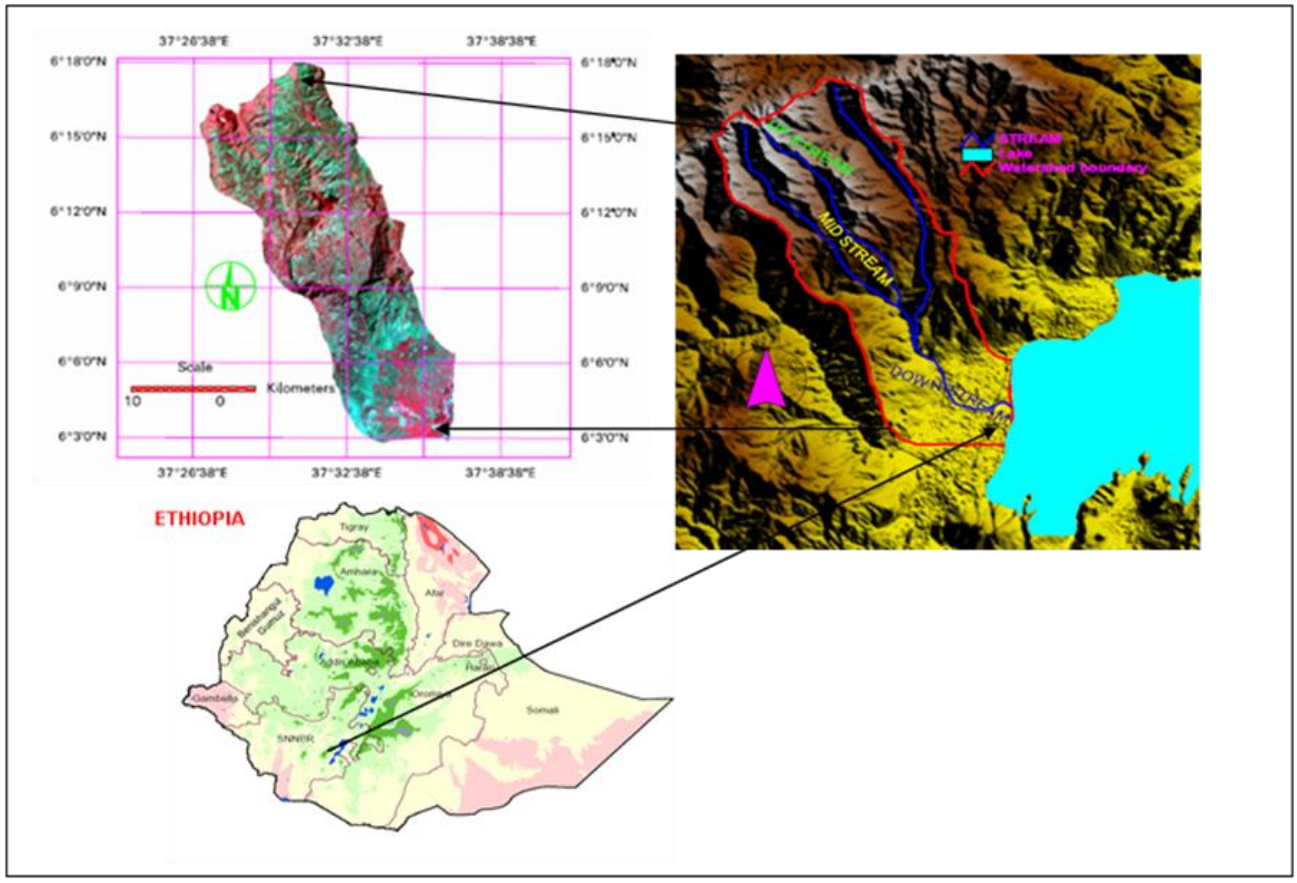


Figure 3.1 Location and Drainage Pattern of HRC (**Source**: Designed via Arc GIS 9.3)

HRC is featured by plain, rugged and undulating landscape, with altitude of 1170 – 3484 m above sea level. 55.8% (13,075.5ha) of HRC is strongly sloping to moderately steep (5 - 15˚), and 12.3% (2,882.2ha) of the area is steep (15 - 30˚) to very steep (> 30˚) (hilly, mountainous or rangy), which is a feature of the MC and UC; but, the portion of the area that is gently sloping to sloping [< 5˚ (8.3%)]

constituted 31.9% (7,475ha)-the lion share of which is part of the LC (Table 5.10b, Appendix III). The main river, Hare, originates roughly at Gughe-Surra Mountain range, drains roughly to the South-Southeast direction, and empties into Lake Abaya within the Ethiopian Rift Valley (Figure 3.1). Gughe-Surra Mountain Range separates HRC from the Omo drainage system, which is situated to the Northwest part of the water-divide. HRC is characterized by dendritic drainage pattern where arrangement of the main river, Hare, and its tributaries appears like a tree (Figure 3.1).

Average annual discharge (volume) of Hare River, recorded for years 1980 - 2006 (by GTSO, 2008) was about 59.166 million $m^3$. The largest total annual discharge of the river was recorded in 1993 (82.94 million $m^3$) and 1986 (82.64 million$m^3$); whereas, the smallest total annual discharge was measured in 1991 (29.31 million $m^3$) (Figure 6.11, Appendix V; GTSO, 2008). Total annual discharge was also relatively low in 1999 (31.79 million $m^3$), 1998 (36.57 million $m^3$), 1990 (39.77 million $m^3$) and 1984 (42.08 million $m^3$) (Figure 6.11, Appendix V); and, data of these periods clearly indicate that total annual discharge of Hare River was low (minimum) during periods (1984, 1990/91, 1998/99) of drought incidence in Ethiopia(GTSO, 2008). Hare is a permanent river and, thus, it is used for irrigation largely in the LC, where 92% of the sample households were beneficiaries of the service.

**(b) Climate and Agro-ecology:**

HRC experiences different agro-climate conditions. Temperature and rainfall data recorded for 29 – 34 years (1982/87 – 2015) in the LC and MC and UC were analyzed (MAE, 2016). The MAT averaged for 29 years of the MC plus UC and the LC showed a spatial variation from $16.7^0$C to 24 $^0$C, respectively; the highest Mean Monthly Temperature (MMT) of the LC ($25.9^0$C) and MC and UC ($18.6^0$C) of HRC was experienced in March (Table 5.8a, Appendix III) due to limited cloud cover and vertical rays of the sun around the equator where this study area is located (that is, within $6^0$ N); but, the lowest MMT was recorded in December ($22.8^0$C) in the LC due to slanting rays resulting from the overhead of sun around $23½^0$ S, which is away from HRC ($6^0$ N). High cloud cover made July the coldest month ($14.9^0$C) in the MC and UC of Hare(MAE, 2016).

MAT of the LC was maximum ($25.1^0$C) in 2009 and minimum ($23.3^0$C) in 1998/2007; and, the relatively large range ($1.8^0$C), standard deviation (SD) ($0.41^0$C) and coefficient of variation (CV) (0.017) indicate that the temporal variability of MAT of the LC (in 1987 – 2015) was substantial (Table 4.5a, Appendix II). The range ($1.1^0$C), SD ($0.30^0$C) and CV (0.018) of the MAT in the *Woina Dega* (Sub-tropical) to

*Dega* (Temperate) area of HRC imply that the year-to-year temperature variation of the MC and UC was also somewhat high (MAE, 2016; Table 4.5a, Appendix II).

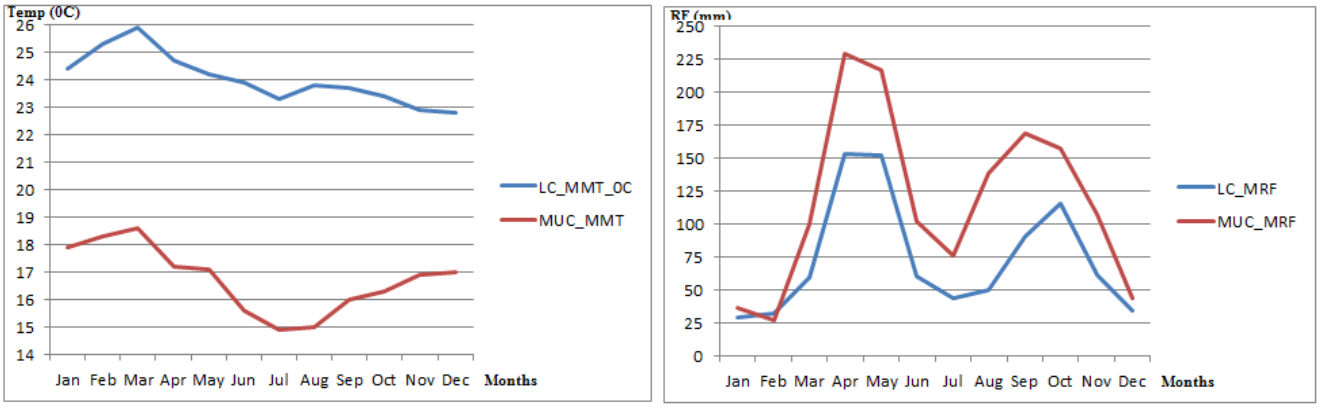


Figure 3.2 Distribution of: **(i)** Mean Monthly Temperature (MMT) Averaged for 1987 – 2015 (Left Fig. above); and, **(ii)** Mean Monthly Rainfall (MMRF) Averaged for 1982 – 2015 (Right Fig) in LC and MUC of HRC. (**Source:** Own Design, 2017 upon Data of MAE, 2016) (**MUC** = **Middle and Upper Catchment**)

Figure 3.2 **(i),** left above, illustrates the distribution of temperature of HRC within a year (meaning, from season to season). Annual range ($3.1^0$C), standard deviation ($0.9^0$C) and Coefficient of Variation (CV) (0.038) of temperature in the real tropical climate of the LC was smaller than the corresponding temperature figures in the temperate (highland) climate of the MC and UC of Hare, which were $3.7^0$C, $1.2^0$C and 0.072, respectively (Table 5.8b, Appendix III; MAE, 2016). The more frequent cloud covers over the highland MC and UC during rainy seasons contributed to higher temperature variability in these areas than that of the low-lying LC (where cloud cover is limited in most of the year).

The mean total annual rainfall of HRC also varies from 883.7 mm of the LC to 1406.5 mm in the MC and UC within 1982 – 2015(MAE, 2016). Hare experiences a bi-modal type of annual rainfall distribution, where March to June is the main rainy season and August/September to November is the 2$^{nd}$ one in the whole HRC [Figure 3.2 (ii)]. Rainfall amount of HRC in the main rainy season peaks in April (231.1mm in MC and UC and 153.7mm in LC); and, in the second rainy season, it becomes maximum in October in the LC (115.6 mm) and September (170.4 mm) in the MC and UC of the Catchment (Table 5.8a, Appendix III). CV of the total annual rainfall of HRC indicated that the year-to-year variability in the LC (with CV of 0.18) was larger than that of the MC and UC (with CV of 0.12) (Table 4.5a, Appendix II) due to rain-shadow effect of the Western Escarpment of the Rift-Valley on the LC, on the one hand, and the Sub-catchment's location adjacent to Abaya lake, on the other hand; meaning, the probability of the

LC to get rainfall is often limited when saturated air originating from Northwest direction of the Escarpment invade the Sub-catchment; but, rainfall more likely occurs as saturated air moves over the LC crossing Abaya lake from the South-Southeast direction. HRC experiences rainfall throughout the year; no month is without rainfall [Figure 3.2 (ii) above]. But, seasonal rainfall variability in the MC and UC (with CV of51.9%) of Hare was slightly larger than its variability in the LC (with CV of 50.7%) (Table 5.8b, Appendix III; MAE, 2016).

HRC, with elevation of 1170 – 3484m above sea level, has agro-ecological zones (Hurni, 1998), which vary from *Kola*/tropical (its South-Southeastern part) to *Wurch*/afro-alpine along and nearby the Ridge extending from Surra (West of Chencha town) to the Northwestern edge of HRC. *Kola* (tropical) (1170 – 1500m), *Woina Dega* (sub-tropical) (1500 – 2300m), *Dega* (temperate) (2300 – 3200m) and *Wurch* (afro-alpine) (3200 – 3484m) agro-climate areas of HRC constituted 24% (5623.9ha), 23.7% (5553.6ha), 48.3% (11318ha) and 4% (937.2ha), respectively (Table 5.10a, Appendix III).

**(c) Soil Resource**:

HRC is endowed with different soil classes due to variation in altitude, climate and vegetation. Fluvisols and leptosols are found in greater part of HRC (Yechale, 2012). The calcaric fluvisols, being a result of alluvial and lacustrine deposit, are dominant in the plain LC of Hare; and, sandy loam, loam or sandy clay to loam (Yechale, 2012), deep, neutral to alkaline, high fertility and productivity are properties of this soil type even if it is susceptible to flood and waterlogging problems (Abren, 2007; Yechale, 2012). The shallow and less fertile leptosols are features of the steep and rugged landscapes of the MC and UC of HRC; cambisols are found in the upper part of the LC where colluvial deposit is frequent; it has a good nutrient storage capacity and fertility condition (Yechale, 2012). Back-slopes of ridges/mountains in the MC and UC are featured by alisols, and foot-slopes of these landscapes are dominated by acrisols (Engidawork, 2001). Acidity, leaching and runoff erosion are key productivity constraints of soils (leptosols, cambisols, alisols and acrisols) in MC and UC of the study area (Abren and Abera, 2012; Yechale, 2012).

**(d) Land Use/Land Cover (LULC) Classes:**

Based on interpretation of aerial photos (1967) and satellite images of 1976, 1985, 1995, 2003 and 2015, about six LULC classes were identified in HRC: that is, forest, riverine vegetation, cropland (and settlement), bush/shrub, woodland and grazing-land (Figure 3.3).Here, these LULC classes are defined

in the context of HRC. *Forest* is composed of trees with minimum height of 5 meters (FAO, 2000) and having nearly closed canopies to interlocked ones. *Riverine vegetation* consists of varieties of trees, woody and herbaceous plants along the banks of Hare River, its tributaries and adjacent to Lake Abaya. *Cropland (and settlement)* refers to land used for rain-fed and/or irrigation-based crop farming including homestead with largely scattered trees (Yachale, 2012). *Bush/shrub-land* is composed more of short, hard woody stem trees (bushes), limited herbaceous plants (shrubs), mixed with grasses and less dense than forests. *Woodland* consists of scattered trees (less than 25 trees/ha) where the physiognomy varies up to 20m depending on composition and density of the undergrowth, more of shrubs and grasses (FAO, 2004). *Grazing-land* is largely grass and herbs intermingled with trees and shrubs with a canopy cover of below 20% and including barren land (Yachale, 2012).

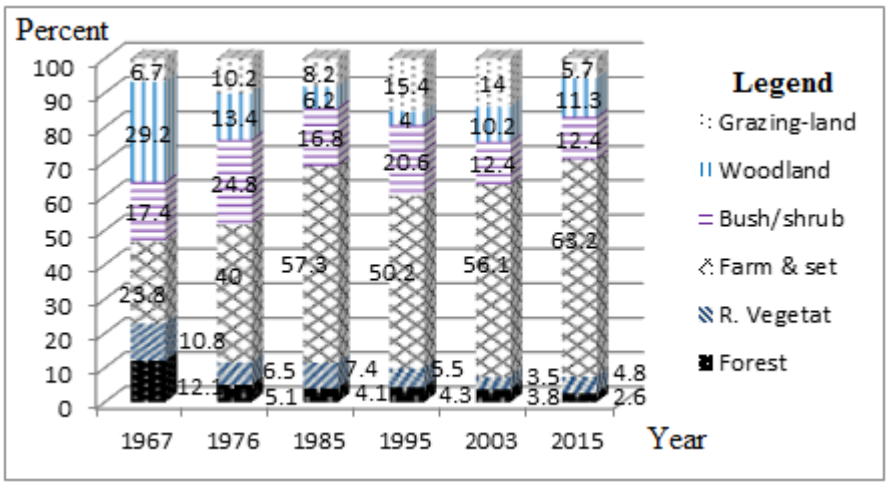


Figure 3.3 Area Share (%) of the Six LULC Classes of HRC in Six Periods (1967 – 2015) [**Source**: Own Design via Excel (2017) upon data in Tables 4.1a, 4.1b, 4.1c, 4.1d, 4.1e and 4.1f, Appendix II]

Figure 3.3 illustrates status of environmental resources (LULC) of HRC for six periods within 1967 – 2015. In 2015, the lion's share (63.2% or 14,809.5ha) of HRC was used for crop farming (plus settlement). Bush/shrub, woodland and riverine vegetation resources constituted 12.4% (2905.6ha), 11.3% (2647.9ha) and 4.8% (1124.8ha) of the study area, respectively. Cropland (plus settlement) expansion, from 23.8% (in 1967) to 63.2% (in 2015), was a key cause of environmental services' value loss in HRC within 1967 – 2015. The Catchment experienced forest degradation from 12.1% (2835.4ha) in 1967 to 2.6% (609.2ha) in 2015; similarly, riverine vegetation had also declined from 10.8% (2530.7ha) in 1967 to 4.8% (1124.8ha) in 2015 (see Figure 3.3).

**(e) Economic Activity:**

HRC is solely inhabited by rural people. So, agriculture is the dominant economic activity in the Catchment. Although both crop production and livestock rearing are practiced by the residents, crop farming is the most important source of livelihood means in the Catchment (Abren and Abera, 2012). Agro-forestry (banana, mango, avocado, papaya, moringa, coffee, etc.,), other fruits (tomato, pepper, etc.,), cereals (maize), pulses (haricot bean), vegetables (cabbage), tuber and root crops (sweet potato, cassava, goderie, onion, etc.,), fibers (cotton), etc., are grown by smallholder farmers of the LC; and, cereals (barley and wheat), pulses (bean and pea), tuber and root (potato, *boye/boyna*, onion, garlic, etc.,), fruits (apple) and *enset* are cultivated by inhabitants in the MC and UC of HRC (Tables 5.1a, 5.1b and 5.1c, Chapter 5). Crop farming in the Catchment is practiced in two seasons annually: that is, during *Belg* or Spring season (March to May/June) and *Meher* or Autumn (August/September to November) season (Abren and Abera, 2012; Yechale, 2012). Generally, over three-fifth (63.2%) of HRC was used for crop farming and settlement in 2015 (Figure 3.3).

The importance of livestock (cattle, sheep, goats, donkeys, etc.,) rising as a source of income for smallholder farmers is insignificant largely in the MC and UC of Hare due to increasing shrinkage of grazing-land (Figure 3.3 above)in these Sub-catchments(MC and UC). Weaving, daily labor, donkey-driven cart and wagon (in LC only), and retailing (petty-trade) are the other income sources for inhabitants of HRC to a limited extent (own questionnaire-based HH survey, 2016 – 2017).

**(f) Population:**

HRC was characterized by scattered settlement since the Catchment was predominantly inhabited by rural people whose principal source of livelihood means originates from agriculture (own observation during field survey during 2016 – 2017). The Catchment was inhabited by 64,671 people, where females constitute 51.6% (33,370) and males account48.4% (31,301) (DANRP, 2015). In the Catchment, nearly 2/3$^{rd}$ (65.5%, 42,331) of the residents were living in the MC and UC and slightly over 1/3$^{rd}$ (34.5%, 22,340) were in the LC (DANRP, 2015). Size of HH in LC of Hare was 4,137; whereas, the MC and UC of the area was inhabited by8,065 HH(DANRP, 2015). Since area of HRC is about 234.33km$^2$ (23,432.7ha), its crude density was 276 persons/km$^2$.

## 3.2 Research Methodology

### 3.2.1 Research Design and Justification

A *research design* is a plan that "involves the intersection of philosophy, strategies of inquiry and specific methods" (Creswell, 2009) of data collection and analysis. Thus, this study was conducted upon the *quantitative research* approach since the philosophical basis of the dissertation is the post-positivist lens (Corbetta 2003; Neuman, 2007; Creswell, 2009); that is, acquisitions and analyses of data were carried out largely using methods of the quantitative approach. Here, the *post-positivist* lens was preferred over the other worldviews as the researcher was curios in translating theories about ecological services dynamics and its change drivers into research questions, acquiring evidences via careful observations and measurements, verifying the theories upon analyses of data and drawing generalization about the issues studied (Creswell, 2009). The decision on the "quantitative approach" has come from the philosophical basis of the study (post-positivism) and also the need for statistical-based inferences about: (a) ESV changes of HRC (1967 – 2015) upon the coefficient of sensitivity analysis- useful for rejecting or accepting the computed ESV changes (Pannell, 2013); (b) whether there were significant variations in average income from crop and fuel-wood products upon gender, HH-size, farm-size, etc., differences among HH; and, (c) the impact of farm inputs (like farm-size, labor, fertilizer, etc.,) on crop harvest, which was measured by coefficient of determination and beta coefficients of regression analysis (Quinn and Keough, 2001; Gujarati, 2004; Bryman, 2006).

On the other hand, *survey (cross-sectional* and *longitudinal) design* is the particular strategy of inquiry, which was used to accomplish this dissertation work(Creswell, 2009). The cross-sectional design was used to acquire and analyze data about cropland and fuel-wood services of HRC at a point of time (that is, 2015/16); whereas, the longitudinal survey design was used to gather time-series data upon which overall changes (trends) of ESV of HRC were analyzed overtime (1967 – 2015). Here, the "survey" design was preferred for this research project due to the fact that (Bryman, 2006; Singh, 2006; Neuman, 2007; Creswell, 2009): first, "survey design" was presumed to yield a breadth of (broad) information on several issues about which investigation is required; second, it enables quick data acquisition and response from representative samples, and also, data analyses that enable inferences from the sample to the population under study; finally, this design is also useful for minimizing the budget required for acquisition and analyses of data (Creswell, 2009).

### 3.2.2 Sources and Instruments of Data Acquisition

Data required for this research were gathered from both primary and secondary sources. Primary data were acquired through instruments like questionnaire, interview and field survey/observation (check-list and unstructured). Data were also acquired from aerial photos (1967), Landsat MSS (1976), and Landsat TM (1985, 1995, 2003 and 2015) images. Records of temperature (1987 - 2015), rainfall (1982 - 2015) and discharge (1980 - 2006) of Hare River were also used for the study.

Questionnaire, as a basis of survey design, was the most important instrument of data collection for this research; this is so because, it is relevant for swift data collection due to immediate response from sample HH; and, acquisition of a wide range of data about multiple attributes or variables is usually possible using this instrument of data gathering (Creswell, 2009). Questionnaire, consisting of close-ended and open-ended questions, was prepared, commented and improved upon comments and further facts from HRC. The questionnaire was split into two: one consisting of questions for the LC, and the other for the MC and UC. The splitting was needed so as to reduce the cost of printing and duplicating the questionnaire. Otherwise, all (100%) questions of the two sets of questionnaires were the same (see Appendix I). Both sets of questionnaires were translated into Amharic, and administered on sample HH by assistants who were capable of communicating to the respondents in both Amharic and '*Gamogna*' (a local language in HRC). It was used to gather data about crop harvest, crop prices, threats, farm inputs (farm size, fertilizer, seeds, seedlings, oxen power, labor, use of water pump motor for irrigation, etc.,) per/HH/year and their costs, amount and price of fuel product consumption (firewood and charcoal), state of environmental resource dynamics, drivers of ES dynamics (gains/losses), etc. To ensure validity and reliability of evidences, data were recollected for those copies of the questionnaire about which responses of sample households seemed to have been speculative (Creswell, 2009).

Interview, consisting of open-ended questions, was prepared focusing on issues that required clarity, confirmation and/or further information; it was used to gather information about farm inputs, challenges of fruit products, productivity/management problems of croplands, causes of ecological changes and resource degradation, etc. Observation was used to capture data about LULC classes (recorded on selected sample sites upon GPS), status of farm-plots, conservation and management measures on croplands, exchange of crop products, etc., using a structured check-list. It (observation) was also used to collect evidences essential for enriching discussion of results. A balance-beam was used to acquire (measure) data about average weight of a shoulder of firewood (19.9kg) and a sack of charcoal (22.7kg)

separately (Table 6.2c, Appendix IV). Secondary data were collected from books, journals/articles, proceedings, dissertations, theses, reports (about population size, household size, meteorological data records, research reports, etc.).

### 3.2.3 Sampling Techniques

A multi-stage sampling was used in this study. Initially, HRC was stratified into LC (1170 – 1600m), MC (1600 - 2400m) and UC (2400 - 3484m) upon change in elevation (Hurni, 1998), vegetation and crops grown. Sample *Kebeles* were selected via simple random and purposive sampling; that is, Chano Chalba KPA was selected from the LC using simple (lottery) random since all the KPA are fully located within Arba Minch Zuria *Woreda* plus the LC; whereas, Shama Gedie and Doko Masho KPA were chosen via purposive sampling from the MC and UC, respectively; here, the criterions of purposive sampling were whether a sample KPA is fully situated within Chencha *Woreda*, and whether its administrative boundary fully lies in the MC or the UC. Such a flexible sampling was preferred as HRC lies almost in Arba Minch Zuria and Chencha *Woreda* Administrations.

Sample size of HH was determined considering whether it enables statistical-based inferences about the study population at least at 95% confidence level. Using $n = \frac{N}{1+N\,(e)2}$ (Jupp, 2006; Penzer, 2011), the minimum sample size was 387 HH for inference at 95% [from 12,202 total HH of fifteen KPA within HRC (DANRP, 2015)], where: 'n' is sample size, 'N'is population and 'e' is standard error(0.05). But, 465 (19.3%) samples were selected using systematic random sampling; that is, starting randomly, every 5$^{th}$ individual was taken from the list of HH of each sample KPA. That is, households of sample KPA such as Chano Chalba (from LC), Shama Gedie (from MC) and Doko Masho (from UC), were about 892, 705 and 809, respectively(DANRP, 2015). Proportionally, 174 (37.4%), 134 (28.8%) and 157 (33.8%) farmers (HH) were selected from Chano Chalba (LC), Shama Gedie (MC) and Doko Masho (UC) KPA, respectively. Experts (8), elder people (6), DA (5) and inhabitants (8) used for interview were selected via purposive sampling; that is, whose total was 27.Accidental or convenient and purposive/judgmental sampling was used to measure weight (using a balance-beam) of: **(i)** six (6) shoulders of firewood from three (3) females and three (3) males, and three from the LC and MC/UC each; and **(ii)**four (4) different sacks of charcoal from three women and one man, and two from the LC (Arba Minch) and MC/UC each (Chencha) (Table 6.2c, Appendix IV).

Sampling design was also required for environmental survey. The 1km$^2$ grid square on the 1:50,000 topo-sheet of HRC was used as a basis for sampling LULC classes. Three (3) grid sample sites were identified from the LC, MC, and UC each for data acquisition via check-lists. The grid sample sites were selected through purposive sampling, that is, from sites where sampling for two, three or more of the LULC classes (among forest, riverine vegetation, cropland, bush/shrub, woodland and grazing-land) was possible. Evidences, about existing LULC classes of each grid sample site, were described and recorded manually, and using camera and GPS.

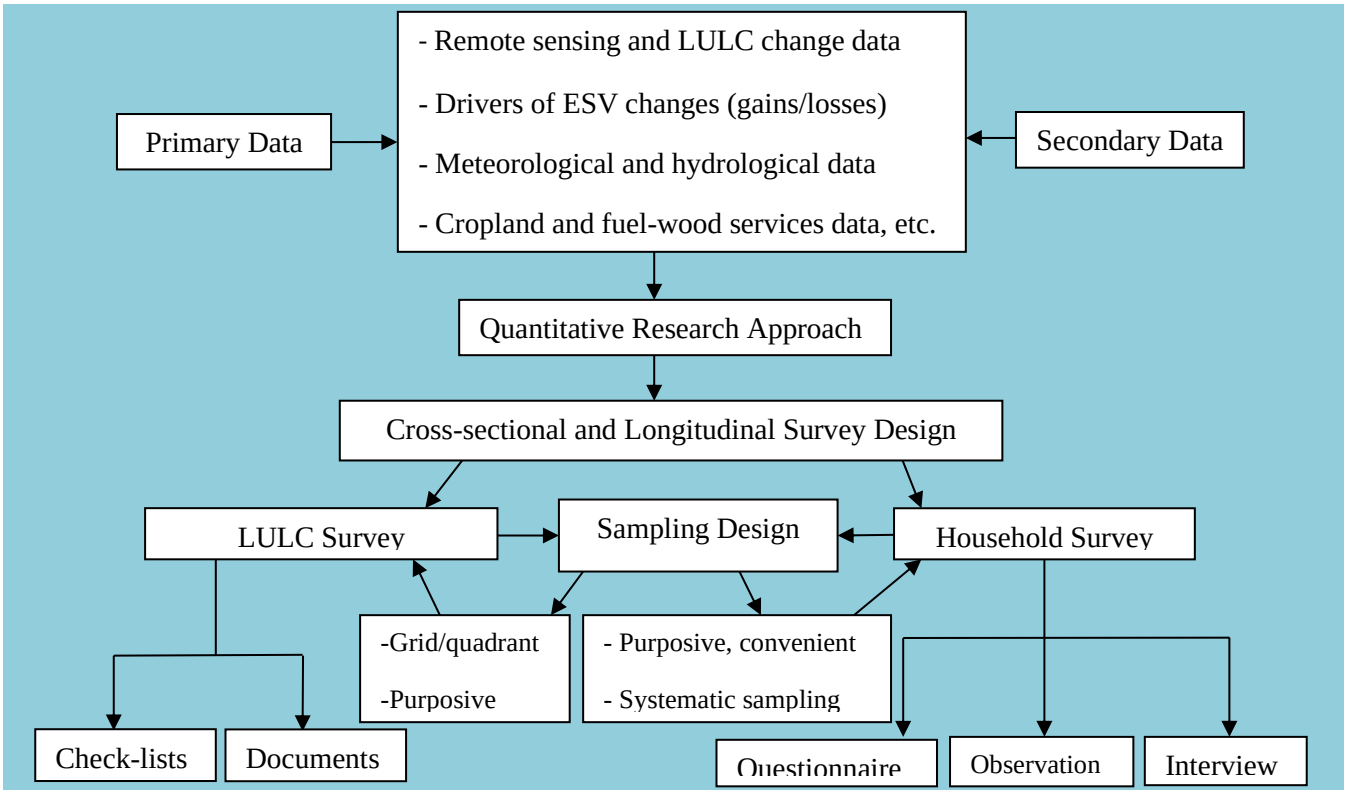

Figure 3.4: Design of the Procedures of Data Acquisition (Source: Own Design, 2017)

### 3.2.4 Methods of Data Analysis

This heading consists of "analysis of value of ecological service dynamics, and meteorological and discharge data," and "analysis of survey data (values of crop and fuel-wood products)."

**(I) Analysis of Value of Ecological Service Dynamics, and Meteorological and Discharge Data:**

Data about status of LULC were acquired from panchromatic aerial photographs of 1967 (obtained from EMA), Landsat MSS of 1976, Landsat TM of 1985, 1995, 2015 and Landsat Enhanced TM Plus (ETM+2003) images. Initially, the 1: 50,000 scale topo-sheets were scanned, geo-referenced and digitized to acquire base-map of HRC (with an area of 23,432.7ha). The aerial photos and Landsat images

were also geo-referenced to UTM geographic projection, using Clarke 1880 spheroid, datum Adindan (Ethiopia) and Zone 37N. Aerial photographs (20 stereo pairs) were scanned with a resolution of 600 dots per inch, and saved in Tag Image Format File (TIFF) for further processing (Yechale, 2012).GLCF, with a website of http://glovis.usgs.gov, was the source of satellite images for this study. Initially, resampling process (at 30m pixel size) was carried out on aerial photos in order to make spatial resolution of the photos uniform with Landsat images of HRC and hence, to resolve or avoid errors that could originate from resolution differences between aerial photos and satellite images. The multi-temporal remote sensing data were imported to image processing software, and hence, image enhancement, rectification and classification were carried out (Yechale, 2012); categories of LULC were identified through a supervised maximum likelihood classification technique via ERDAS 8.6 (Chanhda et al., 2009; Yechale, 2012). Attributes such as pattern, shape, size, texture, tone, association and site were used for identifying LULC classes of HRC within 1967 – 2015 (Lillesand and Kiefer, 2000). Area of each LULC class was computed using Arc-GIS (9.3).

LULC dynamics data were extracted via "change matrix" procedure for all the periods considered. It was assumed that the probability of transition (Pij) for each class in the matrix was proportional to the surface area of the corresponding class that remained unchanged throughout the periods considered (Chanhda et al., 2009; Yechale, 2012). Mathematically: $P_{ij} = S_{ij}(t_1)/ Sj(t_2)$; where: Sij is the surface area of the "ij" element of the LULC transition matrix during each initial year and "Sj" is the surface area of the "j" LULC class in the next year; thus, for any "j" class: SPij =100% (Yechale, 2012).

Areas of six LULC classes and Valuation Coefficients (VC) of Costanza et al (1997) were used for measuring ESV of HRC in 1967, 1976, 1985, 1995, 2003 and 2015. Decisions were made on the local level LULC classes of HRC that could be relevant surrogates for the corresponding global biome categories (Li et al., 2007; Chanhda et al., 2009); and, VC of each LULC class was assigned using "value (benefit) transfer" techniques (Costanza et al., 2006; Kindu et al., 2016) (Table 3.1 below). Based on the VC assigned to each LULC, the total ESV of HRC (in each period) was estimated using the procedure (Kreuter et al., 2001; Li et al., 2007):

$$\mathrm{ESV} = \sum_{1}^{n} (\mathrm{Ak} * Vk);$$

Where: "ESV" is the estimated Ecosystem Service Value, "*Ak"* and "$V_k$*"* refer to the Area and Value coefficient for LULC class "*k"*, and "n" is the number of LULC classes. Value of ES change (gain and/or loss) was measured upon the following model (Yun-guo et al., 2011):

$$G_{xy} = (V_y - V_x)* A_{xy}$$

Where "$G_{xy}$" is the gain and/or loss of ESV after the initial LULC class "x" is changed into class "y" in the next study period, "$V_x$" and "$V_y$" represent the value coefficients for LULC class "x" and "y," respectively, and "$A_{xy}$" is the area change from LULC class "x" to "y" (that is, results of the change matrix's analysis).Since there is no absolute match between local level LULC classes and the global scale biome categories, applying sensitivity analysis is of great worth (Yun-guo et al., 2011; Pannell, 2013). Sensitivity analysis is an assessment of possible changes and errors that may originate from a model and the effects on inferences drawn upon application of the model (Pannell, 2013).

**Table 3.1 LULC Classes of HRC, Its "Valuation Coefficients" (VC) Used for Estimating ESV, and Equivalent Global Biome Classes and their VC**

| N0 | HRC (Hare River Catchment) | | Globe/World | |
|---|---|---|---|---|
| | **LULC Classes** | **VC (US$/ha/Year)** | **Biomes** | **VC (US$/ha/Year)** |
| 1 | Forest | 969 | Tropical forest | 2007 |
| 2 | Riverine vegetation | 969 | Tropical forest | 2007 |
| 3 | Cropland and settlement | 92 | Cropland | 92 |
| 4 | Bush/shrub-land | 232 | Grass/rangeland | 232 |
| 5 | Woodland | 969 | Tropical forest | 2007 |
| 6 | Grazing-land | 232 | Grass/rangeland | 232 |

**Source:** Set upon Costanza et al., (1997); Yun-guo et al., (2011); Kindu et al., (2016); Table 4.6 (Appendix II)

Applying a standard economic sensitivity analysis enables to evaluate how much the temporal ESV changes depend on the VC used, and also to minimize possible errors that may occur due to mismatch between local level ecosystem classes and global scale biome categories. The following statistical tool was applied for this purpose (Yun-guo et al., 2011; Kindu et al., 2016):

$$CS = \frac{(EV_a - EV_i)/EV_i}{(VC_{a_k} - VC_{i_k})/VC_{i_k}}$$

Where, 'CS' is coefficient of sensitivity, EV is the estimated service value, VC is the value coefficient, "a" and "i" refers to the "adjusted" and "initial" values, respectively, and "k" is the land use class. In fact,

VC of all the six LULC classes was adjusted by 50% for the sake of sensitivity analysis even if some of the LULC classes have good fit with definitions in literature (Costanza et al., 1997). Evidences of household survey and change matrix-based measurement of ESV gains/losses were used for analyzing drivers of ESV changes in HRC.

On the other hand, trends of change of temperature, rainfall and river discharge of HRC overtime were analyzed using a simple linear regression, which is expressed as: y = ax + b (Gujarati, 2004; Penzer, 2011); where "x" is "time/year," "b" is constant, "a" is slope (rate of change), and "y" is "temperature or rainfall/discharge" at a time (year).Standard deviation, range and coefficient of variation were used for analyzing variability of temperature, rainfall and river discharge overtime.

**(II) Analysis of Survey Data (Values of Crop and Fuel-Wood Products):**

Data gathered via questionnaire were coded and entered into SPSS (version 20). Descriptive (mean/average, standard deviation, percent) and inferential (correlation, t-test, ANOVA and regression) statistics were used for analyses. Value of crop harvest and fuel-products of HRC were measured upon *market value (prices and costs)* technique (Freeman, 2003). In HRC, over 22 crops were grown in 2015/16 (meaning, 8 were from the MC and UC, and the rest from LC). Crop harvest, and its revenue/income and NEV were estimated upon the procedures below(Moore et al., 2009; Penzer, 2011): ***(i)****Total Harvest (quintal)*: $\mathrm{TH} = \sum_1^n (\mathrm{S} * \mathrm{AH})$, where: TH is Total Harvest, 'S' is HH who cultivated crops "1" to "n," and 'H' is Average Harvest of each crop; ***(ii)****Revenue/income (ETB/US$)*: $\mathrm{R} = \sum_1^n (\mathrm{S} * \mathrm{AH} * \mathrm{AP})$, where: 'R' is Revenue, 'S' is HH who cultivated crops "1" to "n," 'AH' is Average Harvest of each crop, and 'AP' is Average Price of harvest of each crop; and ***(iii)****NEV*: $\mathrm{NEV} = \sum_1^n [(\mathrm{S} * \mathrm{AH} * \mathrm{AP}) - (\mathrm{S} * \mathrm{AI} * \mathrm{AC})]$, where: NEV is Net Economic Value, 'AH' is Average Harvest, 'S' is HH who used each farm input "1" to "n," AI = Average amount of each Input "1" to "n" and 'AC' is Average Cost of each input "1" to "n."

Amount of farm inputs was derived from average amount of each input multiplied by number of HH who used each of the inputs for 2015/16 production season; and, multiplying the total of each input by its average price has enabled estimation of the total cost of all inputs using summation. In principle, capital (like land), labor, equipment, etc., costs should be considered (deducted) in computing net economic value of nature via cropland products (Bishop, 1999; Freeman, 2003). So, costs of farm inputs used for

the production of crops were deduced in order to determine the net value of crop harvest for HH of HRC in 2015/16 (Freeman, 2003). Here, costs were accounted only for inputs, which were acquired by farmers through financial expense such as fertilizer, wage labor, purchased seeds (like maize, onion, barley, wheat, bean, pea and potato), seedlings (like banana, mango and apple), etc. But, no capital cost was allocated on farmland (at HH level) in the estimation of the net value of crop harvest in HRC since land ownership right belongs to the state in Ethiopia (Watson, 2007). "Value (benefits) transfer" technique (Costanza et al., 2006) was used to estimate cropland service value using: $E = \Sigma(Ac*VC)$, where: 'E' is estimated value, 'Ac' is area of cropland -which is obtained through interpretation and analysis of the 2015 satellite image (Landsat TM)of HRC, and 'VC' is Value Coefficient of cropland (Kreuter et al., 2001; Kindu et al., 2016).

Regression analysis was run using SPSS (version 20) for evaluating the impact of HH-related Independent Variables (IV)or farm inputs on the Dependent Variable (DV), that is, crop harvest or produce) using: $Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 + u$ (Gujarati, 2004; Singh, 2006); where: 'Y' is observed cropland produce, 'a' is the constant, $x_1$ is farm size, $x_2$ is labor, $x_3$ is pair of oxen power, $x_4$ is fertilizer, $x_5$ is seedlings, $x_6$ is seeds; and $b_1$ , $b_2$, $b_3$, $b_4$, $b_5$, and $b_6$ are coefficients of $x_1$, $x_2$, $x_3$, $x_4$, $x_5$ and $x_6$ (respectively),'u' is residual [is observed (Y) minus (-) predicted ($\hat{Y}$) produce, or $Y - \hat{Y}$]. But, oxen power was accounted in the analysis for the LC only as its usage in MC and UC was rare. This analysis was made so as to determine the proportion of "produce" that is significantly explained by the IV. Beta coefficients were used to identify the predictor variable/s (farm inputs) with stronger and weaker significant impacts on the DV (crop harvest).

Analysis was also made about the consumption and economic value of fuel-products in HRC. Level of consumption and economic value (ETB/US$) of firewood (FW) and charcoal was summarized using the following procedures (Jubb, 2006; Singh, 2006; Penzer, 2011): ***(i)*** *Total Consumption (TC) in Shoulders or Sacks/or kg/Year*: TC = S*AC, where: 'S' is HH who were consuming "firewood" or "charcoal," and 'AC' is Average Consumption of FW or charcoal***;*** ***(ii)*** *Average Consumption (AC) (Shoulders or Sacks, kg/HH/Year)*: $AC = \frac{TC}{S}$, where: 'TC' is Total Consumption annually and 'S' is HH who were using FW or charcoal; ***(iii)****Total Economic Value (TEV) (US$/Year)*: TEV =S*AC*AP, where: 'S' is HH who use the fuel-products, 'AC' is Average Consumption of FW or charcoal by each HH/year and 'AP' is Average Price of a shoulder of FW or a sack of charcoal; ***(iv)*** *Average Economic Value (AEV)*: $AEV = \frac{TEV}{S}$, where:

'TEV' is Total Economic Value (US$/Year) and 'S' is HH who were using FW or charcoal. Average weight of firewood was computed from six (6) shoulders, and that of charcoal was calculated from four (4) sacks of the fuel product (Table 6.2c, Appendix IV). "Value (benefits) transfer" technique (Costanza et al., 2006) was used to estimate timber, firewood and charcoal value of nature using: $E = \Sigma(Ak*Vk)$, where: 'E' is estimated value, 'Ak' is area of land use 'k,'- which is obtained through interpretation of the 2015 Landsat image (TM) of HRC, and 'Vk' is value coefficient of land use 'k'(Yun-guo et al., 2011).

Per capita income or gross value (per/person/year) from crop harvest and fuel products was computed as a ratio of average income (US$/HH/year) to average HH size of the study area. Similar procedures were used so as to quantify per capita Net Economic Value (NEV) of crop produce, per capita consumption of fuel-products, and per capita income (that is, gross value and NEV) from both cropland and fuel-product services. Mean exchange rate was used to convert the earnings via the products from ETB to US$, which was US$ 1 divided by ETB 21.5 (0.046512) in 2015/16, on average, (NBE, 2016). Finally, analyses results of the different sets of data were organized and interpreted. Simple, compound and composite bar-graphs, line-graphs, figures, etc., were used for presentation of the findings. Discussion was also made about results of the study upon evidences from interview and observation, and also in comparison with empirical evidences of other studies on related issues.

## 3.3 Assumption

Statistical/mathematical and economic assumptions were set pertaining to the models/tools and/or evidences used for measurement and/or analysis in this study (Moore et al., 2009; Penzer, 2011):

**(I) Statistical/mathematical Assumptions:**

1) In the regression analysis, independent variables (farm inputs) were assumed to have a linear (cause-effect) association with the dependent variable (crop produce); $Y = a + b_1X_1 + b_2X_2 + b_3X_3 \ldots + b_nX_n$; where: Y is the dependent variable; $X_1$, $X_2$, $X_3$, $X_n$ are independent variables; $b_1$, $b_2$, $b_3$, $b_n$ are coefficients of $X_1$, $X_2$, $X_3$, $X_n$, respectively (Jupp, 2006);

2) Variables like temperature, rainfall and discharge of HRC were assumed to have a linear cause-effect association with the independent variable, "time/year;" this was mathematically expressed as **y = ax+ b**; where: 'y' is MAT/or total annual rainfall/or annual discharge, 'x' = time (year), "a" is the coefficient of "x" and "b" is a constant. Besides, "time/year" is assumed to be a

substitute of the independent variable, that is, total annual ESV while evaluating the impact of ESV change on temperature, rainfall and discharge of HRC.

3) 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);

4) The study population is assumed to have been normally distributed so that the distribution of the sample mean becomes normal (Moore et al., 2009; Penzer, 2011);

**(II) Economic Assumptions:**

The following basic assumptions were given regarding the allocation of VC used for analysis of ESV dynamics of HRC within 1967 – 2015:

1) Local level LULC classes of HRC were assumed to be approximate surrogates of the global scale biome categories (Kreuter et al., 2001; Kindu et al., 2016), which were given by Costanza et al., (1997); hence, the global scale values (VC) allocated (in US$/ha/year) by Costanza et al., (1997) were used for estimating ESV of HRC in six different periods (1967 – 2015);
2) Even if HRC is largely located within $6^{0}02'13'' - 6^{0}17'55''$ N (tropical region), its forest and woodland resources were assumed to have a VC of 969 $/ha/year each (Kindu et al., 2016)-just value of a normal/average forest (Costanza et al., 1997), which is 48.3% of the VC allocated for "tropical forest or woodland" (2007 $/ha/year each) by Costanza et al., (1997); but, in this study, the figure, 2007 $/ha, is assumed to be value of services offered by rainforests of equatorial region (like Congo, Amazon, etc.,) where mean total annual rainfall is high (1,500 – 2,500mm/year) unlike HRC where mean annual rainfall averaged for 34 years (1982 - 2015) ranges 883.7 – 1,406.5 mm (MAE, 2016);
3) Similarly, riverine vegetation of the area is assumed to provide a service value equivalent to "forest" (969 $/ha/year) upon the idea that, even if riverine vegetation of HRC is composed of more of trees, and less shrubs and grasses, this LULC class (being largely evergreen) is assumed to supplant services value of an average forest assigned by Costanza et al., (1997).

Measurement of current cropland and fuel-wood provisioning services were carried out upon the following assumptions:

1) Seedlings planted in 2015/16 were assumed to have been appropriates urrogate inputs of the corresponding produce obtained from perennial crops (such as banana, mango, *enset* and apple) by smallholder farmers of HRC in the same period;

2) Prices at local markets (within and nearby HRC) during 2015/16, were assumed to have been appropriate bases for measuring economic values of cropland and fuel-wood products of HRC; this is so because, values of crop and fuel-wood products were measured and evaluated from the viewpoint of earnings at HH and individual levels, locally;

3) "Farm size" was used as one independent variable in the regression analysis assuming that 100% of each HH's holding was utilized for the 2015/16 crop harvest in HRC;

4) Labor cost was assumed to be variable (instead of fixed); thus, average wage of daily laborers (per/person/day) in the LC,MC and UC was assumed to be a minimum labor cost; hence, it was used for computing NEV of crop products in the respective Sub-catchments;

5) The total firewood, charcoal and timber consumption by HH of HRC was assumed to have been derived 100% from the existing forest, riverine vegetation, woodland and bush/shrub resources of Hare (that is, not from sources out of HRC);

6) Estimating the net economic values of environmental services requires deducting the costs incurred (or spent) for acquisition of the services from different sources (Freeman, 2003); thus, the estimated value (US$) of firewood and charcoal consumption by HH of HRC (annually) was assumed to have been a net environmental value of the fuel products for residents of the study area (Watson, 2007); this is so because, no (financial) cost was spent for generating these energy products (according to evidences gathered through questionnaire).

## 3.4 Ethical Issues

Ethical issues in research are not methodological concerns; rather, research ethics encompasses "considerations of the conduct of researchers in relation to their own personal behavior as well as how they relate to and treat others during their research" (Connolly, 2003). Generally, research ethics refers to a set of acceptable procedures or norms which have to be practiced (followed) by researchers throughout the steps of research projects (Creswell, 2009).

Necessary ethical considerations were accounted in the instrument (questionnaire) design, data acquisition (survey) and analysis, and reporting of research results (Bryman, 2006). Data from HH of HRC were collected based on "informed consent" of the participants; that is, research objectives and purpose of the survey were clearly informed and communicated, in advance, to the "participants" (sample respondents) in the questionnaire and interview so as to ensure their freedom of choice (that is, the decision to participate or not participate) (Connolly, 2003; Bryman, 2006; Creswell, 2009). Data were recollected for those copies of the questionnaire about which responses of sample households seemed to have been speculative (Creswell, 2009). The necessary incentives were also guaranteed to survey assistants and data collectors used in the study (Connolly, 2003).

As sample representativeness is a strict requirement of survey research design (unlike the other research designs), continuous efforts were made to realize the participation of every sample selected for the data acquisition using questionnaire (Creswell, 2009).To this end, a tight follow-up was made on data collectors during questionnaire administration by the researcher so as to ensure the return of all copies of the questionnaire from all sample households and also to minimize response bias (from the side of data collectors).Anonymity of participants was protected during reporting results of the study (Connolly, 2003; Bryman, 2006); that is, gender, age, profession/occupation, place of residence, etc., (Connolly, 2003) were used for reporting evidences obtained from interviewees (from HRC).

# Chapter Four

# Analysis of Values and Impacts of Ecosystem Service Dynamics in HRC

## 4.1 Status of ESV of HRC within 1967 – 2015

Results of the study about the estimated Ecosystem Service Value (ESV) of HRC for periods 1967, 1976, 1985, 1995, 2003 and 2015 were summarized below (Table 4.1). ESV of HRC was the highest (US$ 13,664,000) in the earliest period (1967), which was followed by the estimated ESV of the area in 1976 (US$ 8,425,000). Forest, riverine vegetation and woodland of HRC provide provisioning services (like water supply, food production services, raw materials and genetic resources), regulatory services (such as water, climate, gas and disturbance regulation, erosion and biological control, and waste treatment), supportive services (such as nutrient cycling, pollination and soil formation) and cultural services (like recreation, aesthetics, spiritual, etc.,) (Table 4.6, Appendix II; Costanza et al., 1997; Kindu et al., 2016). The estimated value of these services of Hare was the largest for woodland (US$ 6,630,000 or 48.5%) in 1967, followed by ESV of forest (2,758,000 or 20.2%) and riverine vegetation (2,457,000 or 18%) (Table 4.1).

**Table 4.1Level of Annual ESV (US$ '000') of HRC in 1967, 1976, 1985, 1995, 2003 and 2015**

| LULC Class | Annual ESV in US$ ('000') | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1967 | | 1976 | | 1985 | | 1995 | | 2003 | | 2015 | |
| | ESV | P (%) | ESV | P (%) | ESV | P (%) | ESV | P (%) | ESV | P (%) | ESV | P (%) |
| Forest | 2,758 | 20.2 | 1,146 | 13.6 | 925 | 14.0 | 975 | 15.8 | 864 | 13.0 | 586 | 8.9 |
| Riverine vegetation | 2,457 | 18.0 | 1,470 | 17.5 | 1,683 | 25.5 | 1,240 | 20.1 | 793 | 12.0 | 1,100 | 16.7 |
| Cropland and settle* | 512 | 3.7 | 862 | 10.2 | 1,236 | 18.7 | 1,082 | 17.6 | 1,208 | 18.3 | 1,362 | 20.6 |
| Bush/shrub | 945 | 6.9 | 1,350 | 16.0 | 914 | 13.8 | 1,121 | 18.2 | 674 | 10.2 | 674 | 10.2 |
| Woodland | 6,630 | 48.5 | 3,043 | 36.1 | 1,408 | 21.3 | 908 | 14.8 | 2,316 | 35.0 | 2,566 | 38.9 |
| Grazing | 362 | 2.7 | 554 | 6.6 | 443 | 6.7 | 834 | 13.5 | 758 | 11.5 | 308 | 4.7 |
| Total | **13,664** | **100** | **8,425** | **100** | **6,609** | **100** | **6,160** | **100** | **6,613** | **100** | **6,596** | **100** |

**Source:** Own Computation (2017) upon Table 4.6, Appendix II (*Settle = Settlement)

The 1967estimated values of bush/shrub (US$ 945,000 or 6.9%), cropland (US$ 512,000 or 3.7%) and grazing-land (US$ 362,000 or 2.7%) services of HRC were limited. These figures of bush/shrub (US$ 945,000 or 6.9%) and grazing-land (US$ 362,000 or 2.7%) were the sum monetary values of provisioning

(like food production) service, regulatory (such as water and gas regulation, erosion and biological control, and waste treatment) services, supportive (pollination and soil formation) services, and cultural (recreational) services obtained from bush/shrub and grazing-land resources of HRC in 1967 (Table 4.6, Appendix II; Costanza et al., 1997; Kindu et al., 2016). Similarly, the estimated cropland value (US$ 512,000 or 3.7%) was also the aggregate of food production, biological control and pollination services of croplands of HRC in 1967 (Table 4.6, Appendix II). Nine years later (in 1976), ESV of woodland (US$ 3,043,000 or 36.1%), forest (US$ 1,146,000 or 13.6%) and riverine vegetation (US$ 1,470,000 or 17.5%) significantly dropped; whereas, ESV of cropland (US$ 862,000 or 10.2%), bush/shrub (1,350,000 or 16.0%) and grazing-land (US$ 554,000 or 6.6%) increased(Table 4.1). The share of grazing-land in the total ESV of the Catchment was still limited in 1976.

The estimated ESV of riverine vegetation (1,683,000 or 25.5%), woodland (US$ 1,408,000 or 21.3%) and cropland (US$ 1,236,000 or 18.7%) was somewhat large nine (9) years later in 1985 when the total ESV of HRC was US$ 6,609,000 annually. The minimum ESV (US$ 443,000 or 6.7%) was estimated for grazing-land. Forest (US$ 925,000 or 14%) and bush/shrub-land (US$ 914,000 or 13.8%) ESV was also limited, then. Overall ESV of HRC (US$ 6,160,000) in 1995 was the smallest of all the periods accounted in the study; this is because, significant increase was observed in the area extent of bush/shrub and grazing-land for which smaller "valuation coefficient" was assigned (Costanza et al., 1997); in fact, smaller "value coefficients" of bush/shrub and grassland were reflections of the extent (type) of services given by each of these natural resources (Costanza et al., 1997).Anyway, a better level of ESV was quantified for riverine vegetation (US$ 1,240,000 or 20.1%), bush/shrub (US$ 1,121,000 18.2%) and cropland (US$ 1,082,000 or 17.6%) services in 1995 (Table 4.1).

ESV of HRC was also estimated for periods 2003 and 2015 (Table 4.1 above). The 2003 total ESV of the Catchment (US$ 6,613,000) was larger than that of 2015 (US$ 6,596,000). Woodland ESV, with the respective amount of US$ 2,316,000 (35%) and US$ 2,566,000 (38.9%), was the largest in both 2003 and 2015. Value of cropland service was the second most important contributor to the overall ESV of HRC in 2003(US$ 1,208,000 or 18.3%) and 2015 (US$ 1,362,000 or 20.6%). Service values of other land covers were limited in 2003 and 2015 (except the 2015 ESV of riverine vegetation, US$ 1,100,000) (Table 4.1). Generally, increasing extent of woodland (1995 – 2003 and 2003 – 2015) played a pivotal role for improvement of ESV of HRC in the last two decades (1995 – 2015), underlain by expansion of agro-forestry (mango, avocado, banana, etc.,) practices in LC (Abren, 2007).

## 4.2 Magnitudes, Trends and Drivers of Values of ES Dynamics in HRC

Ecological services undergo change overtime. Tables 4.2a and 4.2b illustrate magnitude and rate of ESV dynamics of HRC within 1967 – 2015. Figures of "gross ESV gain/loss" (second row from bottom in Tables 4.2a and 4.2b) were computed without considering "change matrix" data; whereas, values of "net ESV gain/loss" (bottom row) were calculated upon LULC change matrix data.

**Table 4.2a: Magnitude (M) of Change, Annual Rate (AR) of Change, Gross and Net Gain/Loss of ESV of HRC within 1967 – 1976, 1976 – 1985 and 1985 – 1995:**

| N0 | Land Use/Land Cover Class | **ESV Change (Gain/Loss) in US$ '000'** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **1967 – 1976** | | | **1976 – 1985** | | | **1985 – 1995** | | |
| | | M | % | AR (%) | M | % | AR (%) | M | % | AR (%) |
| 1 | Forest | -1612 | -58.4 | -6.5 | -221 | -19.3 | -2.1 | 50 | 5.4 | 0.5 |
| 2 | Riverine vegetation | -987 | -40.2 | -4.5 | 213 | 14.5 | 1.6 | -443 | -26.3 | -2.6 |
| 3 | Cropland and settlement | 350 | 68.4 | 7.6 | 373 | 43.2 | 4.8 | -154 | -12.5 | -1.3 |
| 4 | Bush/shrub-land | 405 | 42.9 | 4.8 | -440 | -32.5 | -3.6 | 207 | 22.6 | 2.3 |
| 5 | Woodland | -3587 | -54.1 | -6.0 | -1635 | -53.7 | -6.0 | -500 | -35.5 | -3.6 |
| 6 | Grazing-land | 192 | 53.0 | 5.9 | -111 | -20.0 | -2.2 | 391 | 88.3 | 8.8 |
| | Gross ESV gain/loss | **-5239** | **-38.3** | **-4.3** | **-1816** | **-21.6** | **-2.4** | **-449** | **-6.8** | **-0.7** |
| | Net ESV gain/loss | **-5370** | **-39.3** | **-4.4** | **-1777** | **-21.1** | **-2.3** | **-388** | **-5.9** | **-0.6** |

**Source:** Own Computation (2017) upon Table 4.1 above; Tables 4.2a, 'b'and'c,' Appendix II

During 1967 – 1976, high magnitude of ESV loss was observed from woodland (by US$ 3,587,000 or 54.1%), forest (by US$ 1,612,000 or 58.4%) and riverine vegetation (by US$ 987,000 or 40.2%); and the annual rate of ESV decline of woodland, forest and riverine vegetation was estimated at 6.0% (US$ 398,556), 6.5% (US$ 179,111) and 4.5% (US$ 109,667), respectively, on average. However, service value gain (growth) was experienced through increasing bush/shrub-land (by US$ 405,000 or 42.9%), cropland and settlement (by US$ 350,000 or 68.4%), and grazing-land (by US$ 192,000 or 53%) in the same period (1967 – 1976). Net ESV loss by about 39.3% (US$ 5,370,000) was the ultimate effect of LULC change within 1967 – 1976, which indicates that ESV of HRC had declined by 4.4% (US$ 596,667) per year during this period (Table 4.2a). Such a high magnitude and rate of net ESV loss of HRC was triggered largely by expansion of cropland (plus settlement) and bush/shrub cover into woodland, forest and riverine vegetation in 1967 – 1976 (Table 4.1a and 4.2a, Appendix II).

Woodland, bush/shrub and forest had experienced significant ESV loss by about US$ 1,635,000 (53.7%), 440,000 (32.5%) and 221,000 (19.3%), respectively, during 1976 – 1985; and, the annual rate of ESV loss due to transformation of the respective LULC classes was about 6% (US$ 181,667), 3.6% (US$ 48,889) and 2.1% (US$ 24,556) in 1976 – 1985. Grazing-area change-induced loss of ESV was about US$ 137,000 (19.5%) in the same period. Whereas, cropland (US$ 373,000 or 43.2%) and riverine vegetation of HRC (213,000 or 14.5%) revealed an ESV increase within 1976 – 1985; that is, where service value of the respective LULC classes had grown by 4.8% (US$ 41,444) and 1.6% (US$ 23,667) annually in the period. The net ESV loss due to LULC change (1976 – 1985) was about 21.1% (US$ 1,777,000) of the total ESV of the area; meaning, ESV of HRC had declined by about 2.3% (US$ 197,444) annually in nearly a decade (Table 4.2a). Change of woodland, forest, riverine vegetation and bush/shrub resources into cropland and settlement was the main reason for the high magnitude of net ESV loss of HRC within 1976 – 1985 (Table 4.1b and 4.2b, Appendix II). Establishment of the irrigation-based State Farm in LC in the 1950s (according to an elder, 64) and migration from highlands of Gamo and Wolayta to the LC (by 52.9% of the HH-own survey) was the root cause of ESV loss during 1967 – 1976 and 1976 – 1985.

Evaluation was also made about the status of ESV of HRC for a decade within 1985 – 1995 (Table 4.2a). A significant ESV decline, by 26.3% (US$ 443,000), 12.5% (US$ 154,000) and 35.5% (US$ 500,000), was observed in response to the change of riverine vegetation, cropland and woodland, respectively; in other words, ESV loss triggered by change of the respective LULC classes was 2.6% (US$ 44,300), 1.3% (US$ 15,400) and 3.6% (US$ 50,000) per year within 1985 – 1995. A seemingly unique experience during this period was the raise of forest ESV by 5.4% (US$ 50,000) as a result of slight increase in its area (by 71.5ha) (Table 4.1c, Appendix II); here, rise in ESV of forest had emanated mainly from the transformation of cropland and bush/shrub into forest, underlain by (according to the 49 year expert) afforestation and restricted illegal forest exploitation [that is, De-Groot et al.'s (2010) positive drivers of ESV change] during socialist gov't of Ethiopia (1985 – 1995). ESV gain was also observed from the change of grazing-land (US$ 391,000 or 88.3%) and bush/shrub (US$ 207,000 or 22.6%). Increasing grazing-land and bush/shrub induced growth of ESV, respectively, was about 8.8% (US$ 39,100) and 2.3% (US$ 20,700) per annum in 1985 – 1995. Synergy (aggregate effect) of the 1985 – 1995 LULC dynamics on ESV of HRC was also negative (US$ -388,000) even if its magnitude of service value loss was by far smaller than that of 1967 – 1976 and 1976 – 1985; the net ESV loss was about 5.9% (US$

388,000); this means, ESV of the area had dropped by 0.6% (US$ 38,800) annually within 1985 – 1995 (Table 4.2a).

**Table 4.2b: Magnitude (M) of Change, Annual Rate (AR) of Change, Gross and Net Gain/Loss of ESV of HRC within 1995 – 2003, 2003 – 2015 and 1967 – 2015:**

| N0 | Land Use/Land Cover Class | Change (Gain/Loss) ofESV (US$ '000') | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1995 – 2003 | | | 2003 – 2015 | | | 1967 – 2015 | | |
| | | M | % | AR (%) | M | % | AR (%) | M | % | AR (%) |
| 1 | Forest | -111 | -11.4 | -1.4 | -278 | -32.2 | -2.7 | -2172 | -78.8 | -1.6 |
| 2 | Riverine vegetation | -447 | -36.1 | -4.5 | 307 | 38.7 | 3.2 | -1357 | -55.2 | -1.2 |
| 3 | Cropland and settlement | 126 | 11.7 | 1.5 | 154 | 12.8 | 1.1 | 850 | 166.0 | 3.5 |
| 4 | Bush/shrub-land | -447 | -39.9 | -5.0 | 0 | 0.0 | 0.0 | -271 | -28.7 | -0.6 |
| 5 | Woodland | 1408 | 155.1 | 19.4 | 250 | 10.8 | 0.9 | -4064 | -61.3 | -1.3 |
| 6 | Grazing-land | -76 | -9.1 | -1.1 | -450 | -59.4 | -5.0 | -54 | -14.9 | -0.3 |
| | Gross gain/loss | **453** | **7.4** | **0.9** | **-17** | **-0.3** | **-0.02** | **-7068** | **-51.7** | **-1.1** |
| | Net gain/loss | **443** | **7.2** | **0.9** | **-19** | **-0.3** | **-0.02** | **-7039** | **-51.5** | **-1.1** |

**Source:** Own Computation (2017) upon Table 4.1 above; Tables 4.2d, 'e'and'f,' Appendix II

The level of dynamics of ESV of HRC was also measured for periods 1995 – 2003, 2003 – 2015 and 1967 – 2015 (Table 4.2b). During 1995 – 2003, significant decline of ESV had been experienced as a result of the change in bush/shrub (US$ 447,000 or 39.9%), riverine vegetation (US$ 447,000 or 36.1%) and forest cover (US$ 111,000 or 11.4%). In other words, the rate of ESV loss (effected by the declining area size of the respective LULC classes) was about 5% (US$ 55,875), 4.5% (55,875) and 1.4% (13,875) annually within 1995 - 2003. An estimated ESV loss by about 9.1% (US$ 76,000) was also observed due to shrinkage of grazing-land in the same period. Expansion of cropland and settlement into bush/shrub, riverine vegetation, forest and grazing-land was the main cause for the decline of ESV from these LULC classes within 1995 – 2003 (Table 4.1d, Appendix II).

On the contrary, a huge gain of ESV (by US$ 1,408,000 or 155.1%) was observed from the raise in the area extent of woodland within 1995 – 2003. That is, increasing area of woodland had resulted in a rise of ESV by about 19.4% (US$ 176,000) per year within 1995 – 2003. Transformation of large area of cropland and bush/shrub into woodland had greatly contributed to the huge growth of ESV of woodland in HRC, then (Table 4.1d, Appendix II); and, the increase in woodland extent, in turn, have emanated

from the expansion of tree-(fruit) crops such as mango in LC (Abren and Daniel, 2007) and apple in the UC (Seifu et al., 2014). A service value gain of about 11.7% (US$ 126,000) was also observed as a result of increasing area of cropland. Unlike the three earlier periods (1967 – 1976, 1976 – 1985 and 1985 – 1995), the synergic impact of LULC dynamics within the eight-year duration (1995 – 2003) was a net gain/rise in the overall ESV of HRC by about 7.2% (US$ 443,000); this means, level of ESV of HRC grew by 0.9% (US$ 55,375) annually (Table 4.2b).

ESV of grazing-land and forest has dropped by about 59.4% (US$ 450,000) and 32.2% (278,000), respectively, during 2003 – 2015; that is, grazing-land and forest shrinkage–induced ESV loss was about 5% (US$ 37,500) and 2.7% (US$ 23,167) annually in the twelve-year duration, respectively. However, riverine vegetation, cropland and woodland ESV of HRC have revealed growth by the respective proportions of US$ 38.7% (307,000), 12.8% (US$ 154,000) and 10.8% (US$ 250,000); and where the estimated annual increase of ESV due to the change of the three LULC classes (in their order) was about 3.2% (US$ 25,583), 1.1% (US$ 12,833) and 0.9% (US$ 20,833). Anyway, HRC revealed a limited net ESV loss by about 0.3% (US$ 19,000) within 2003 – 2015; that is, where the overall ESV of the Catchment has dropped by 0.02% (US$ 1,583) per/year (Table 4.2b). Net ESV loss of HRC (in 2003 – 2015) was largely triggered by the change of forest, bush/shrub and grazing-land into cropland, and the transformation of woodland into bush/shrub in the same period (Table 4.1e, Appendix II). Positive drivers (actions) of ESV changes (De-Groot et al., 2010)] such as (even if limited) area-closure, afforestation, controlled resource use, etc., by the current local gov't (according to an expert, 49) had also resulted in rising area and ESV of woodland – a key cause for reduced level of ESV loss within 2003 – 2015 (Table 4.2d, Appendix II).

HRC experienced the largest amount of ESV loss by 61.3% (US$ 4,064,000) and 78.8% (US$ 2,172,000) due to dwindling supply of woodland and forest, respectively, within 1967 – 2015, where ESV of the respective resource types has diminished by 1.3% (US$ 84,667) and 1.6% (US$ 45,250) annually. ESV of riverine vegetation (55.2% or US$ 1,357,000) and bush/shrub (28.7% or US$ 271,000) have also exhibited decline (loss) within forty-eight years; that is, where the rates of ESV loss of the respective LULC classes were estimated at 1.2% (US$ 28,271) and 0.6% (US$ 5,646) per year. During 1967 - 2015, a gross ESV gain/increase (by 166% or US$ 850,000) was experienced in response to cropland expansion in HRC in four-five decades; and, where cropland ESV of the area has been growing at 3.5% (US$ 17,708) annually in 48 years. The synergic impact of LULC dynamics on ESV of HRC was a net loss by

about 51.5% (US$ 7,039,000); this implies that ESV of the area has been decreasing by about 1.1% (US$ 146,646) each year within 1967 – 2015 (Table 4.2b). Figure 4.1 illustrates trend of ESV (US$) of HRC within 1967 – 2015. ESV of the area was assumed to have changed in a linear model (equation) as: **ESV** = -695.3t + 11,331 (Figure 4.1); and, using this equation, ESV loss of HRC was estimated at US$ 5,073,300 in the period studied. Therefore, it can be concluded that ESV loss of the area was about US$ 5.0573 – 7.0390 million within 1967 – 2015.

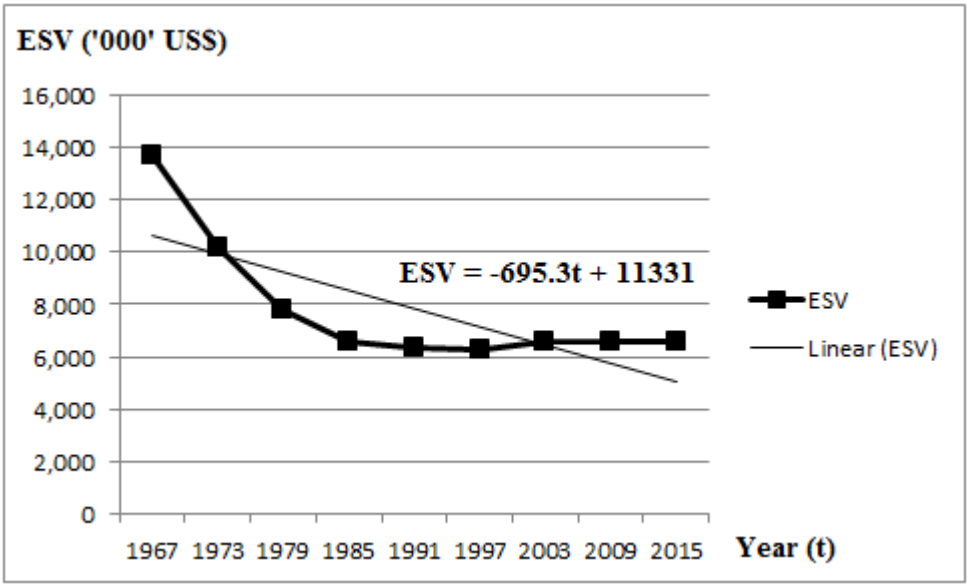


Figure 4.1 Trend of ESV Change of HRC ('000' US$) in 1967 – 2015; [**Source**: Own Design via Excel, 2017]

Expansion of cropland (plus settlement) and bush/shrub at the cost of forest, woodland and riverine vegetation was the principal cause for the huge amount of ESV loss of HRC in 48 years (Table 4.1f and Table 4.2f, Appendix II). HH of HRC also revealed that exploitations of fuel-products (99.6% firewood and 28.2% charcoal), building materials (53.6%), and over-browsing and overgrazing (35.1%) were the other causes for the alteration of forest, woodland, etc., into bush/shrub and the associated ESV loss (Figure 4.3, Appendix II). Generally, the high net ESV loss (by 51.5% or US$ 7,039,000) of HRC in four-five decades has emanated from the dwindling supply of provisioning (like water supply, food production, raw materials and genetic resources), regulatory (such as water, climate, gas and disturbance regulation, erosion and biological control, and waste treatment), supportive (such as nutrient cycling, pollination, etc.,) and cultural (like recreation, aesthetics/spiritual, etc.,) services of forest, riverine vegetation and woodland at large.

## 4.3 Sensitivity Analysis about Estimated Values of Ecosystem Service Changes

Results about the effect of adjusting VC on the estimated ESV gains/losses and also the Coefficient of Sensitivity (CS) associated with the adjustments were summarized below (Table 4.3). Values of the CS for grazing-land were as low as 0.03 and 0.05 in 1967 and 2015, respectively; this means, ESV of Hare Catchment was found to raise by 0.03% and 0.05% for 1% increase in the VC of grazing-land in 1967 and 2015, respectively (Table 4.3).

**Table 4.3: Effect of Changing Valuation Coefficient (VC) and the Coefficient of Sensitivity (CS) Associated with Adjustment of VC**

| LULC | 1967 | | 1976 | | 1985 | | 1995 | | 2003 | | 2015 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | CS | % | CS | % | CS | % | CS | % | CS | % | CS |
| F_VC ±50% | ±10.1 | 0.20 | ±6.8 | 0.14 | ±7.0 | 0.14 | ±7.9 | 0.16 | ±6.5 | 0.13 | ±4.4 | 0.09 |
| RV_VC ±50% | ±9.0 | 0.18 | ±8.7 | 0.17 | ±12.7 | 0.26 | ±10.1 | 0.20 | ±6.0 | 0.12 | ±8.3 | 0.17 |
| CS_VC ±50% | ±1.9 | 0.04 | ±5.1 | 0.10 | ±9.4 | 0.19 | ±8.8 | 0.18 | ±9.1 | 0.18 | ±10.3 | 0.21 |
| B/S_VC ±50% | ±3.5 | 0.07 | ±8.0 | 0.16 | ±6.9 | 0.14 | ±9.1 | 0.18 | ±5.1 | 0.10 | ±5.1 | 0.10 |
| W_VC ±50% | ±24.3 | 0.49 | ±18.1 | 0.36 | ±10.7 | 0.21 | ±7.4 | 0.15 | ±17.5 | 0.35 | ±19.5 | 0.39 |
| G_VC ±50% | ±1.3 | 0.03 | ±3.3 | 0.07 | ±3.4 | 0.07 | ±6.8 | 0.14 | ±5.7 | 0.12 | ±2.3 | 0.05 |

**Source:** Own Computation, 2017

Relatively larger coefficients were computed for woodland and riverine vegetation, where the coefficients range within 0.15 (1995) – 0.49 (1967) and 0.12 (2003) – 0.26 (1985) for the respective LULC classes in all the periods studied; in other words, ESV of HRC was proved to have increased in proportions of 0.15 – 0.49% and 0.12 – 0.26% for a 1% raise in the respective VC of woodland and riverine vegetation. Cropland revealed the smallest CS (0.04) in 1967 and the largest CS (0.21) in 2015; that is, ESV of the study area has changed by 0.04% in 1967 and by 0.21% in 2015 for 1% adjustment/alteration in the VC of cropland (Table 4.3). Similar interpretation holds for CS of other LULC classes in all the periods considered by the study. Findings of the study indicated that the CS values of all the LULC classes were less than 1.0 (Table 4.3); it means, the estimated ESV change of HRC was relatively inelastic with respect to the VC used for estimation. This, in turn, confirms the accuracy of estimations made about local level ESV dynamics of HRC upon existing and/or adjusted VC of Costanza et al, (1997).

Again, ESV (US$ '000') of HRC was estimated after adjusting VC, and the magnitude of changes and effect of changing VC were also measured for all the periods studied (Table 4.4a and 4.4b, Appendix II). However, ESV measured upon adjusted VC and the corresponding ESV changes presented, here, were results of the 1967 and 2015) only just for the sake of illustrating the results briefly. However, ESV measured upon adjusted VC and the corresponding ESV changes presented, here, were results of the initial (1967) and final (2015) periods only just for the sake of illustrating the results briefly. Adjusting VC is found to have its own effect on the estimated ESV change of each ecosystem classes and also the overall ESV of the Catchment. A reduction of total ESV of HRC by about 54.2% (US$ 8,154,000) was the result of increasing VC of forest by 50% for the duration 1967 – 2015, which is a bit larger than the initial proportion of decline (that is, 51.5% - the figure before adjustment of VC); but, the overall ESV of the area dropped by about 48.7% (US$ 5,982,000) when the VC of forest is reduced by 50% (Table 4.4b, Appendix II). Increasing/decreasing VC of forest by 50% affected more the estimated ESV of 1967 (by ±10.1%) than that of 2015 (by ±4.4%) (Table 4.3 above).

Estimated ESV of HRC was found to decrease by 47.7% (US$ 6,643,000) and 55.9% (US$ 7,493,000) when VC of cropland was raised by 50% and reduced by 50%, respectively, in 1967 – 2015% (Table 4.4b, Appendix II). But, adjusting VC of cropland by ±50% impacted more the estimated value of 2015 (by ±10.3%) than that of 1967 (by ±1.9%). ESV changes of the Catchment impacted by adjustment of VC by ±50% were within 48.7% - 53.6% for LULC classes other than forest and cropland (Table 4.4b, Appendix II); and these values were around the proportion of net ESV change (that is-51.5%), which was estimated before adjusting VC of each LULC category (Table 4.2b above).

## 4.4 Impacts of Ecosystem Services Dynamics (Losses) in HRC

The declining trend of ESV of HRC within 1967 – 2015 has been impacting the temperature, rainfall (Figures 4.2a and 4.2b below, and Table 4.5a in Appendix II), and discharge of Hare River overtime (Figure 4.3 below). Mean Annual Temperature (MAT) of the LC (24 $^0$C), and MC and UC (16.7$^0$C) within 1987 – 2015 revealed a crucial variability. Variability (CV) of average annual temperature in almost three decades (1987 – 2015) was about 1.71% (0.0171) in LC and 1.79% (0.0179) in MC and UC of Hare (Table 4.5a, Appendix II).Temperature variation within a year was also high in the study area, where the coefficient of variation in LC was 3.8% and it was 7.2% in the MC and UC (Table 5.8b, Appendix III); the greater temperature variability of the MC and UC of Hare within the twelve months of the year is due to higher cloud cover over the middle and upper catchments during June, July and

August (but, this is not the case in LC where cloud cover is limited in these and other months). The LC of Hare experienced increasing trend in MAT ($^0$C) (Figure 4.2a and Table 4.5a, Appendix II). Estimated upon the linear model (equation): y = 0.0229x + 23.622, MAT ($^0$C) of the LC was 23.7$^0$C at the base year (1987), and it became 24.3$^0$C in 2015; thus, the MAT ($^0$C) difference in 29 years was estimated at 0.6$^0$C. This implies that MAT ($^0$C) of the LC exhibited rising trend by 0.6$^0$C within 1987 – 2015. Average annual temperature of the LC of Hare was deviating by (a CV of) 1.71% from the 3 decades' (1987 – 2015) mean, on average (Table 4.5a, Appendix II).

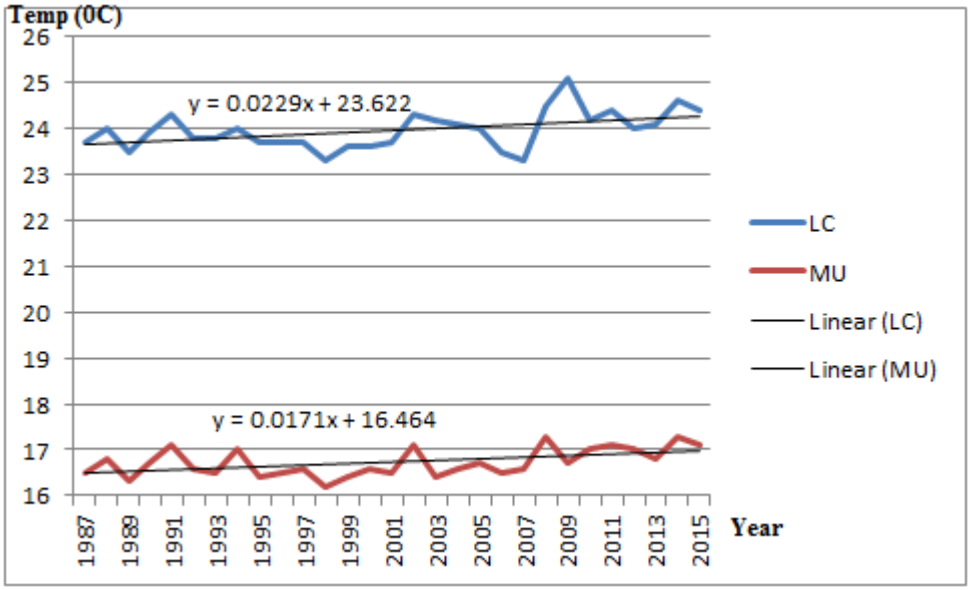


Figure 4.2a Trend of Mean Annual Temperature ($^0$C) of the LC, and the Middle and Upper (MU) Sub-Catchments of Hare within 1987 – 2015 (**Source**: own design via excel, 2017)

The MC and UC of Hare also exhibited an increasing trend in MAT ($^0$C). The MAT ($^0$C) trend of the MC and UC (within 1987-2015) was modeled as y = 0.0171x+16.464 (Figure 4.2a). MAT of the MC and UC (estimated upon y = 0.0171x + 16.464) was 16.5$^0$C in the initial year (1987) and 17$^0$C in the final reference year (2015), where the difference was about 0.5$^0$C. This shows that the MC and UC of Hare also revealed a MAT rise by 0.5$^0$C within 1987 – 2015. The rising trend of temperature in the MC and UC of Hare could also be proved from the gradually increasing altitudinal extent of breeding ground for mosquito, a vector of malaria (according to the 63 year-old interviewee and own observation during 2015 – 2017) from the LC (with elevation of 1,170 – 1,500m a.s.l) up to Dorzie (a village in the MC where its elevation is within 1,500 – 2,400m). The significant positive association of average annual temperature ('r'being0.461$^{**}$) with increasing "time/year" also confirms the rising temperature trend of HRC overtime (at 99% confidence level) (Table 4.5b, Appendix II).MAT of the MC and UC was also deviating from

the average by (a CV of) 1.79% within 1987 – 2015 (Table 4.5a, Appendix II). Generally, the rising temperature (MAT) overtime looks more evident in the LC ($0.6^0$C) than the MC and UC ($0.5^0$C). In fact, temperature rise in the LC of Hare could have been steeper than this figure had cropland expansion into forest and woodland not been (partly) a replacement by agro-forestry or tree crops such as banana, mango, avocado, papaya, coffee, etc. Anyway, increasing surface temperature of HRC overtime was mainly a consequence of increasing concentration of green-house gases such as $CO_2$ in the atmosphere, which was triggered by decreasing climate and gas regulation (carbon sink)value/role of forest and woodland resources of the catchment within 1967 – 2015; that is, where ESV loss (including climate and gas regulation service) of forest (-78.8% or US$ 2,172,000) and woodland (-61.3% or US$ 4,064,000) of HRC was significant in four-to-five decades (1967 – 2015) (see Table 4.2b on page 55).

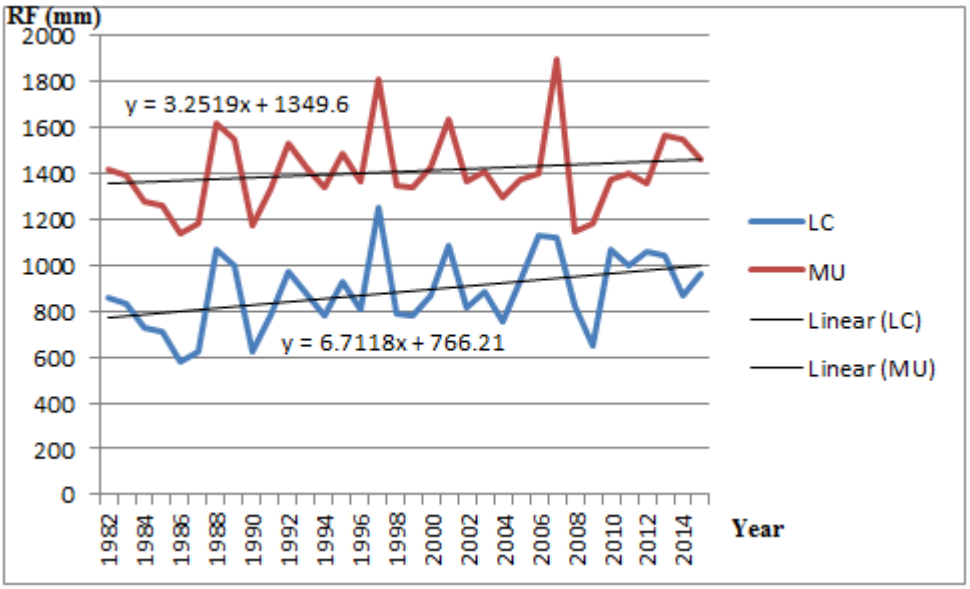


Figure 4.2b Trend of the Mean Total Annual Rainfall (RF in mm) in the LC, and Middle and Upper (MU) Sub-Catchments of Hare within 1982 – 2015 (**Source**: own design via excel, 2017)

A change was also observed in the total annual rainfall in HRC in response to the change (loss) in ESV of the Catchment overtime (Figure 4.2b). That is, increase in average annual temperature (1987 – 2015) was accompanied by an increase in total annual rainfall within 1982 – 2015. Estimated upon the linear regression equation: y = 6.7118x + 766.21 (Figure 4.2b), total annual rainfall of the LC during 1982 was772.9 mm and 987.7 mm in 2015; and, where the difference was about 214.8 mm. This means, total annual rainfall of the LC revealed a rise by 214.8 mm in 34 years (1982 – 2015). Similarly, total annual rainfall of the MC and UC, estimated upon the model y = 3.2519x + 1349.6 (Figure 4.2b), was about

1,352.9 mm in 1982 and 1,456.9 mm in 2015. This indicates that total annual rainfall of the Sub-catchment increased by about 104 mm within 1982 – 2015. The significant positive association of total annual "rainfall" (with 'r' value of0.519$^{**}$) with increasing "time" at 99% level of confidence also confirms the rising rainfall trend of HRC overtime (Table 4.5b, Appendix II). Standard deviation of total annual rainfall of the LC, and the MC and UC was 160.6 mm and 168.7 mm for 34 years, respectively; and, its Coefficient of Variation (CV) in the LC was 0.182 (18.2%) and in the MC and UCwas 0.120(12%) then (Table 4.5a, Appendix II). This implies that total annual rainfall of HRC was fluctuating from the mean total by (a CV of) 12% - 18.2% (from year-to-year), on average.

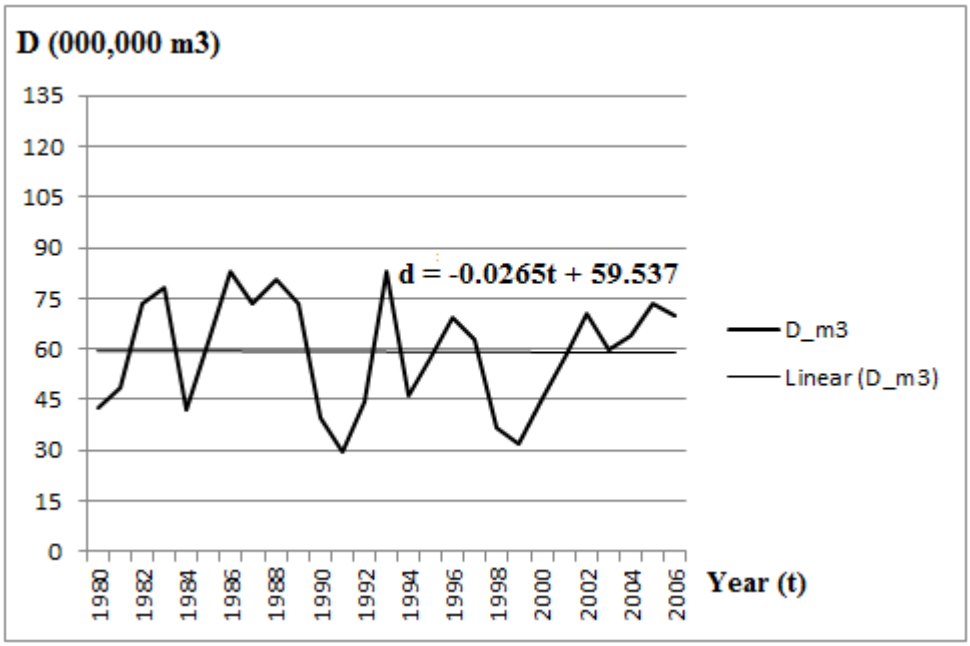


Figure 4.3 Trend of Total Annual Discharge (D) of Hare River ('000,000' m$^3$) within 1980 – 2006 (**source**: Own design via excel, 2017upon Data of Figure 6.11 (Appendix V) and GTSO (2008)

Impact of ESV loss was also reflected from the change in discharge data of Hare River, which were recorded for years 1980 – 2006 (GTSO, 2008)). Average annual discharge of the river was about 59.166 million m$^3$. Annual amount of its discharge was fluctuating (on average) by about (SD) 16.280 million m$^3$from year to year within 1980 – 2006; its coefficient of variation was 0.275; this means, discharge of the river was fluctuating by 27.5% from year-to-year, on average. Anyway, flow data of Hare River clearly indicate that its total annual discharge was minimum during periods of drought incidence in Ethiopia (1984, 1990/91, 1998/99) (Figure 6.11a, Appendix V). Annual water discharge of Hare River also revealed a declining trend within 1980 – 2006 (Figure 4.3). Total annual discharge (**d**) (million m$^3$)

to the increasing "time" (**t**)association was modeled as **d** = -0.0265t + 59.537; that is, using this equation, annual discharge was estimated at 59.5105 million $m^3$ in 1980 and 58.8215 million $m^3$in 2006. Thus, annual discharge difference of Hare River became -0.689 million $m^3$ within 1980 – 2006.This means, annual water flow of the river had declined by 689,000 $m^3$ in 27 years, which adversely affects irrigation value of the river especially in LC where rainfall (883.7 mm) is scarce. The decline of discharge was also proved from its negative relationship with increasing "time" (year) even if the association was not significant both at 99% and 95% (with 'r' value of-0.200 and sig value of 0.242) (Table 4.5b, Appendix II). This implies that the magnitude of decline of discharge (1980 – 2006) was not statistically significant. Of course, annual discharge of HRC should have revealed an increasing trend as total annual rainfall does. But, this was not observed as river discharge is impacted by diverse factors like rainfall amount, geology (permeability of rocks), evaporation, land cover, slope gradient, infiltration, erosion, silt deposition, deforestation (Waugh, 1990), etc.; that is why although discharge was positively associated with rainfall (with 'r' value of 0.033 and sig value of 0.846), the relationship was not significant at 99% and 95% (Table 4.5b, Appendix II). Declining discharge of Hare River (1980 – 2006) was caused by increasing evaporation resulting from rising temperature trend of HRC by 0.5 – $0.6^0$C within1987 – 2015 (Table 4.5a, Appendix II); this in turn was underlain by decline ESV of forest and woodland for carbon sink. It could also be a result of decline erosion control service rooted by dwindling forest, woodland, etc., supply in the MC and UC, and increasing silt deposition in lower course of the river (LC); increasing silt deposition, again, leads to diminishing river depth and discharge thereby enhancing through-flow in the plain, lower course of Hare River.

## 4.5 Discussion

HRC has experienced a net ESV loss in response to LULC changes within 1967 – 2015; and, this was similar with results of other studies (Kreuter et al., 2001; Li et al., 2007; Yun-guo et al., 2011; Kindu et al., 2016); but, studies with positive ESV changes (net gain) (Chanhda et al., 2009) were rare. The net ESV loss of HRC was drastic within the first eighteen years (1967 – 1985) due to reasons attributable to: (i) the dramatic expansion of cropland at the cost of woodland, forest, bush/shrub and riverine vegetation (especially in LC of Hare) within 1967 – 1985, which was more or less similar to the experience of Borena area (South Wollo) within 1972 – 1985 (Abate, 2011); (ii) the high service value (VC) given by forest (US$ 969/ha/year), riverine vegetation (US$ 969/ha/year) and woodland (US$ 969/ha/year) (Costanza et al., 1997); and, (iii) the low service value (VC) obtained from croplands (US$ 92/ha/year)

(Costanza et al., 1997); that is, a value that couldn't compensate or substitute ESV of forest, riverine vegetation and/or woodland (kindu et al., 2016) as the VC of cropland (per/ha/year) is less than one-tenth of the VC of each of these LULC classes.

Net ESV loss of HRC during 1985 – 1995 was relatively low (US$ - 388,000) in comparison with 1967 – 1976 and 1976 – 1985 due to the change of cropland into forest (Yechale, 2012; Denberu, 2015), resulting in net growth of forest cover by 96.2 ha (Table 4.1c, Appendix II); of course, the reduced cropland area then (1995) could, perhaps, be due to change of maize-dominated farming into agro-forestry (like banana, mango) largely in LC (Abren, 2007; Denberu, 2015). Net ESV gain of HRC during 1995 – 2003 was due to high magnitude of change of cropland and bush/shrub into woodland, and bush/shrub into riverine vegetation, that is, a change from LULC classes with small VC to those with too large VC (Costanza et al., 1997; Kindu et al., 2016)-which makes the net ESV change positive. Decline of ESV of forest, bush/shrub, woodland, riverine vegetation and grazing-land in HRC was triggered by increasing crop farming, which was more or less similar to the situation of Tigray highlands (Meles et al.,2008), Borena area of South Wollo (Abate, 2011) and Sheka District in Southwest Ethiopia (Hiywot, 2014). This means, crop farming has long been a major cause of ESV loss [that is, a negative driver of ESV change – a scenario of De-Groot et al., (2010)] by depleting products, species diversity, habitat provision, carbon sink, etc., services of forest and woodland (Li et al., 2007; Zhang et al., 2007; Maeda et al., 2010) in HRC. Forest and woodland depletion-induced ESV loss for gas and climate (carbon sink) regulation (Costanza et al., 2014) resulted in rise of temperature and rainfall in the area. Severe soil erosion (in MC and UC), and flood hazards in the LC (Yechale, 2012) were also adverse effects of cropland expansion-led loss of regulatory services **(**Maeda et al., 2010) in HRC, underlain by population pressure (Belay, 2002).Generally, dynamics of ESV in HRC was triggered by *negative* (farm expansion, fuel-wood and timber extraction-led deforestation, over-browsing, etc.,),*positive* (afforestation, area-closure, resource protection, etc.,)and *neutral*(LULC change) drivers of change (De-Groot et al., 2010). LULC alteration as a *neutral* change driver, exerting negative and positive effects on ecological services (De-Groot et al., 2010), contributed to the high magnitude of net ESV loss within 1967 – 1985, to the net gain of ESV within 1995 - 2003and to the limited net ESV loss in 2003 – 2015 in HRC.

# Chapter Five

# Valuation of Cropland Provisioning Products of HRC

## 5.1 Production and Revenue/Income from Croplands of HRC

HRC (especially the LC) is endowed with diverse species of crops since it reflects a tropical climate. Produce and revenue from croplands of the LC, MC and UC of HRC (for 2015/16) were organized in Tables 5.1a,5.1band 5.1c below. Provisioning products of croplands, in the LC of HRC, are derived from agro-forestry (banana, mango, avocado, papaya, etc.,), cereals (maize and *teff*), pulses (haricot bean), tuber and root crops (cassava, sweet potato, onion, etc.,), vegetables (cabbage, moringa, etc.,) other fruits (tomato, pepper, etc.,) and fibers (cotton). Over half (55%) of the total crop harvest was obtained from banana followed by mango (20.3%), onion (7.9%) and maize (7.3%); but, the level of harvest from other crops of the Sub-catchment was limited in 2015/16 (Table 5.1a).

**Table 5.1a: Share (%) of Crop Producers, Amount of Production [Quintal/Year (Q/Y)] and Mean Price/Quintal (MP/Q) of each Crop, and Estimated Income from the Crops in the LC, 2015/16**

| N0 | Crops | Producers | | Amount of Production (Q/Y) | | | MP/Q | | Income (US$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N0 | P (%) | Mean | Total | P (%) | ETB | US$ | US$ | P (%) |
| 1 | Banana | 157 | 90.2 | 21.6 | 3,391.2 | 55.0 | 569 | 26.5 | 89,866.8 | 53.2 |
| 2 | Mango | 116 | 66.7 | 10.8 | 1,252.8 | 20.3 | 538 | 25.0 | 31,320.0 | 18.5 |
| 3 | Tomato | 59 | 33.9 | 4.9 | 289.1 | 4.7 | 668 | 31.1 | 8,991.0 | 5.3 |
| 4 | Avocado | 51 | 29.3 | 1.0 | 51.0 | 0.8 | 694 | 32.3 | 1,647.3 | 1.0 |
| 5 | Papaya | 28 | 16.1 | 1.4 | 39.2 | 0.7 | 508 | 23.6 | 925.1 | 0.5 |
| 6 | Maize | 155 | 89.1 | 2.9 | 449.5 | 7.3 | 610 | 28.4 | 12,765.8 | 7.6 |
| 7 | Haricot b. | 54 | 31.0 | 0.5 | 27.0 | 0.4 | 738 | 34.3 | 926.1 | 0.5 |
| 8 | Cassava | 53 | 30.5 | 0.6 | 31.8 | 0.5 | 600 | 27.9 | 887.2 | 0.5 |
| 9 | Sweet p. | 68 | 39.1 | 0.7 | 47.6 | 0.8 | 651 | 30.3 | 1,442.3 | 0.9 |
| 10 | Onion | 46 | 26.4 | 10.5 | 483.0 | 7.9 | 702 | 32.7 | 15,794.1 | 9.3 |
| 11 | Pepper | 26 | 14.9 | 1.1 | 28.6 | 0.5 | 600 | 27.9 | 797.9 | 0.5 |
| 12 | *Teff* | 33 | 19.0 | 0.4 | 13.2 | 0.2 | 1564 | 72.7 | 959.6 | 0.6 |
| 13 | Cabbage | 10 | 5.8 | 3.2 | 32.0 | 0.5 | 468 | 21.8 | 697.6 | 0.4 |
| 14 | Cotton | 45 | 25.9 | 0.6 | 27 | 0.4 | 1600 | 74.4 | 2,008.8 | 1.2 |
| | **Total** | | **-** | **-** | **6,163.0** | **100** | **-** | **-** | **169,029.6** | **100.0** |

Source: Own Computation (2017)upon Own Field Survey Data (2016 – 2017)

Average crop harvest (35.4 quintals/HH/year) of the LC was relatively large due to fertile soil condition (Yechale, 2012) andbetter farm-size (0.60 ha/HH) (Table 5.12, Appendix III). There was a significant variation in crop harvest among HH of the Sub-catchment upon differences in “farm size” (sig value of

0.000), “HH size” (sig value of 0.000), amount of “fertilizer” (sig value of 0.000), “labor” (sig value of 0.000) and “oxen power” (sig value of 0.000) used by farmers in 2015/16 at 95% confidence level; but, gender difference-based produce variation was not statistically significant (at 0.05 level) where its F statistic was 3.615 and sig value was 0.059 (Table 5.1d, Appendix III). Besides, the significant positive association of crop produce with farm size ($0.85^{**}$), oxen power ($0.71^{**}$), labor ($0.86^{**}$), fertilizer ($0.70^{**}$), seeds ($0.49^{**}$) and seedlings ($0.45^{**}$) at 0.01 level revealed that average “harvest” was larger for smallholder farmers who used more amount of these farm inputs; but, it was low for those HH with limited use of these inputs (Table 5.1a, Appendix III).

In comparison with the shares (%) in the total produce, the share of banana (53.2%) and mango (18.5%) within the estimated income from crop harvest revealed slight decline. The shares of onion (9.3%), maize (7.6%) and tomato (5.3%) in the estimated revenue were also somewhat good (Table 5.1a above). Revenue proportion of each of the other crops was too limited. Average earning from crop harvest by HH of the LC of Hare was estimated at US$ 971.4 per/HH/year; and the corresponding per capita income of the area was about US$ 194.3 per/person/year(Table 5.7a, Appendix III). However, average income from crop harvest revealed a significant variation among smallholder farmers of the LC upon differences in “farm-size” (with sig value of 0.000) and “family size” (with sig value of 0.000) at 95% confidence level (Table 5.1e, Appendix III); that is, where average income from crop harvest was higher for those HH who have larger average farm-size and average family size.

However, level of produce and revenue from croplands of the LC (according to a farmer informant, 38) is adversely impacted by nature of the products cultivated; that is, most of the products (including tomato) are fruits and, thus, are perishable due to the hot climate where the annual temperature is about $24^0$c (MAE, 2016); the same person revealed that this problem is aggravated when customers fail to receive the products as soon as the fruits are ready for harvest especially during excess production; in such cases, the producers are forced to sell fruits at unfairly cheaper prices, feed the products for livestock and/or dispose the fruits due to spoilage problem. Lack of preserving facilities or other options also threatens the level of earnings of farmers from fruit products of the Sub-catchment. In fact, moisture stress is also a vital constraint of crop-farming in LC [as the mean annual rainfall within 1982 – 2015 was about 883.7mm (MAE, 2016)]; but, this problem has (partly or fully) been overcome with the provision of irrigation service, where 92% of the HH were beneficiaries of the service.

As one moves from the tropical agro-ecology of the LC to the rugged and hilly MC and UC of HRC, the diversity of crops decreases. Potato (98.5%), barley (97.8%) and *enset* (94%) are cultivated by over 90% of the farm HH in the MC; and, over three-fourth (75.6%) of the total harvest of the MC in 2015/16 was derived from potato (41.1%), barley (19.9%) and *enset* (14.6%). Contribution of apple (10.4%) and wheat (8.8%) to the total harvest was also good; but, amount of produce obtained from other crops (like bean, pea and garlic) was limited (Table 5.1b below).

**Table 5.1b Share (%) of Crop Producers, Amount of Production [Quintal/Year (Q/Y)] and Mean Price/Quintal (MP/Q) of each Crop and Estimated income from the Crops in MC, 2015/16**

| N0 | Crops | Producers | | Amount of Production (Q/Y) | | | MP/Q | | Income (US$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N0 | P (%) | Mean | Total | P (%) | ETB | US$ | US$ | P (%) |
| 1 | Barley | 131 | 97.8 | 2.1 | 275.1 | 19.9 | 963 | 44.8 | 12,324.5 | 18.4 |
| 2 | Wheat | 87 | 64.9 | 1.4 | 121.8 | 8.8 | 1257 | 58.5 | 7,125.3 | 10.6 |
| 3 | Apple | 41 | 30.6 | 3.5 | 143.5 | 10.4 | 2205 | 102.6 | 14,723.1 | 22.0 |
| 4 | Bean | 52 | 38.8 | 0.8 | 41.6 | 3.0 | 1165 | 54.2 | 2,254.7 | 3.4 |
| 5 | Pea | 41 | 30.6 | 0.6 | 24.6 | 1.8 | 1637 | 76.1 | 1,872.1 | 2.8 |
| 6 | Potato | 132 | 98.5 | 4.3 | 567.6 | 41.1 | 446 | 20.7 | 11,749.3 | 17.6 |
| 7 | *Enset* | 126 | 94.0 | 1.6 | 201.6 | 14.6 | 1750 | 81.4 | 16,410.2 | 24.5 |
| 8 | Garlic | 9 | 6.7 | 0.5 | 4.5 | 0.3 | 2150 | 100.0 | 450.0 | 0.7 |
| | **Total** | **134** | **100** | **-** | **1,380.3** | **100** | - | **-** | **66,909.2** | **100.0** |

Source: Own Computation (2017) upon Own Field Survey Data (2016 – 2017)

The 2015/16 average produce of the MC was estimated at 10.3 quintal/HH. Amount of crop harvest exhibited significant variation among smallholders of the MC upon difference in "gender," "HH size," "farm size," "fertilizer" and "labor" used for production at 95% confidence level, where significance values of all were less than 0.05 (0.000) [Table 5.1f (i), Appendix III]. That is, average harvest of male-headed HH was significantly larger than that of female-headed ones; besides, farmers, having larger "HH size" and "farm size," and who used more amount of "fertilizer" and labor" inputs obtained larger average harvest during 2015/16. This fact was also well supported by the significant positive association of "farm size" (0.74**), "fertilizer" (0.61**), "labor" (0.76$^{**}$) and "HH size" (0.37**) with amount of crop "harvest" at 99% confidence level [Table 5.1b (i), Appendix III].

A better income was estimated to have been obtained from products of *enset* (24.5%), apple (22%), barley (18.4%) and potato (17.6%) by smallholders of the MC of HRC. The revenue from products of other crops, however, was limited, excepting wheat, 10.6%, (Table 5.1b). Differences in proportions between

production and revenue from each crop harvest were greater for some crops (like apple and *enset*) due to higher market prices of the products. But, the share of potato harvest within the estimated income (revenue) of the MC was 23.5% smaller than its proportion in the total production of crops in 2015/16 because of its low price (Table 5.1b). The estimated average revenue (US$ 499.3) from crop produce of the MC was significantly smaller than that of the UC (US$ 556.5) in 2015/16 (Table 5.7a, Appendix III). Per capita income (US$ 99.9/person/year)from crop harvest of the MC was also smaller too(Table 5.7a, Appendix III). "Gender," "HH size," "farm size," "fertilizer" and "labor" difference-based variation of average earning from crop harvest was also significant among HH of the MC at 95% confidence level where significance values of all these variables were less than 0.05 (that is, all were 0.000) [Table 5.1f (ii), Appendix III].

**Table 5.1c Share (%) of Crop Producers, Amount of Production [Quintal/Year (Q/Y)] and Mean Price/Quintal (MP/Q) of each Crop and Estimated income from the Crops in the UC, 2015/16**

| N0 | Crops | Producers | | Amount of Production (Q/Y) | | | MP/Q | | Income (US$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N0 | P (%) | Mean | Total | P (%) | ETB | US$ | US$ | P (%) |
| 1 | Barley | 146 | 93.0 | 2.4 | 350.4 | 17.1 | 963 | 44.8 | 15,697.9 | 18.0 |
| 2 | Wheat | 110 | 70.1 | 1.3 | 143.0 | 7.0 | 1257 | 58.5 | 8,365.5 | 9.6 |
| 3 | Apple | 51 | 32.5 | 3.5 | 178.5 | 8.7 | 2205 | 102.6 | 18,314.1 | 20.9 |
| 4 | Bean | 83 | 52.9 | 0.9 | 74.7 | 3.6 | 1165 | 54.2 | 4,048.7 | 4.6 |
| 5 | Pea | 60 | 38.2 | 0.4 | 24.0 | 1.2 | 1637 | 76.1 | 1,826.4 | 2.1 |
| 6 | Potato | 157 | 100.0 | 6.8 | 1,067.6 | 52.2 | 446 | 20.7 | 22,099.3 | 25.3 |
| 7 | *Enset* | 133 | 84.7 | 1.5 | 199.5 | 9.8 | 1750 | 81.4 | 16,239.3 | 18.6 |
| 8 | Garlic | 13 | 8.3 | 0.6 | 7.8 | 0.4 | 2150 | 100.0 | 780.0 | 0.9 |
| | **Total** | **157** | **100** | **-** | **2,045.5** | **100** | - | **-** | **87,371.2** | **100.0** |

Source: Own Computation (2017) upon Own Field Survey Data (2016 – 2017)

Crops such as potato (100%), barley (93%), *enset* (84.7%), wheat (70.1%) and bean (52.9%) are grown by more than half of the total farm HH of the UC (each) (Table 5.1c). Level of production (52.2%) of potato alone exceeds over half of the total amount of crop harvest by HH of the Sub-catchment in 2015/16. Amount of production of barley (17.1%), *enset* (9.8%) and apple (8.7%) was also somewhat better (Table 5.1c). Average amount of produce (13 quintal/HH) obtained from the eight (8) crops by smallholders of the UC was also relatively smaller even if it was better than that of the MC (10.3 quintal/HH) (Table 5.7a, Appendix III). But average crop harvest revealed significant variation among HH of the Sub-catchment (UC) at 95% confidence interval upon difference in gender, HH size, farm-size, labor and fertilizer used for 2015/16 production season, where significance values of all these

variables were less than 0.05 [Table 5.1g (i), Appendix III]. Meaning, average harvest of female-headed HH from all the eight crops of the UC was significantly smaller than that of the male counterparts. Similarly, average production was also significantly smaller for households who used smaller average amount of farmland, labor and fertilizer for 2015/16 crop harvest.

Proportion of estimated income (US$) from potato (25.3%), apple (20.9%), *enset* (18.6%) and barley (18%) production by HH of the UC was relatively good; but, the earning from production of the other crops was too limited (see Table 5.1c above).In comparison to the high proportion (52.2%) of potato within the total production of the UC, the smaller share of estimated income (25.3%) from harvest of the tuber (potato) crop was due to its cheap price locally. Average estimated income from crop harvest by smallholders of the UC (US$ 556.5) was somewhat small; and the per capita income (US$ 111.3/person/year) from produce of all crops was also small (Table 5.7a, Appendix III). "Gender," "farm-size," "labor" and "fertilizer" use-difference based variation of average income from crop produce (among HH) of the Sub-catchment was significant at 95% level of confidence, where the respective F statistics of these variables were 11.4, 76.7, 57.8 and 20.7; and, the significance values were all less than 0.05(0.000 - 0.001) [Table 5.1g (ii), Appendix III]; that is, average income from crop harvest was significantly larger for male-headed HH, and farmers who used larger average "farm-size," "labor" and "fertilizer" amount for 2015/16 production season. Level of harvest and income from croplands of the UC and MC is adversely influenced by steepness of farmland, runoff erosion, soil acidity, and poor fertility and productivity of land (Yechale, 2012).

Crop harvest by HH of HRC revealed a significant variation among smallholders based on disparities in "farm size," "gender," "HH size," "labor," "fertilizer" and "seedling" amount used for production in 2015/16, where significance values of all these variables were less than 0.05(0.000) (Table 5.1h, Appendix III). Generally, slightly less than two-third (64.3%) of the estimated total crop harvest of HRC was acquired from the LC in 2015/16, followed by the UC (21.3%) and MC (14.4%) (Figure 5.2 below). Average crop produce by farmers of overall HRC was estimated at about 20.6 quintals per/HH/year; and, the level of harvest (per/HH/year) ranged from a minimum of 2 quintals in the MC and UC to a maximum of 119 quintals in LC (Table 5.7a and 5.7b, Appendix III).Variation in average crop harvest of HH between the LC and MC, the LC and UC, and the MC and UC was statistically significant at 95% confidence level (Table 5.6a, b and c, Appendix III). In other words, average crop harvest by smallholder farmers of the LC (35.4 Quintal/HH/year) was significantly larger than that of the UC (13 quintal) and

the MC (10.3 quintal) in 2015/16, and average harvest of the UC also exceeds significantly that of the MC in the same season.

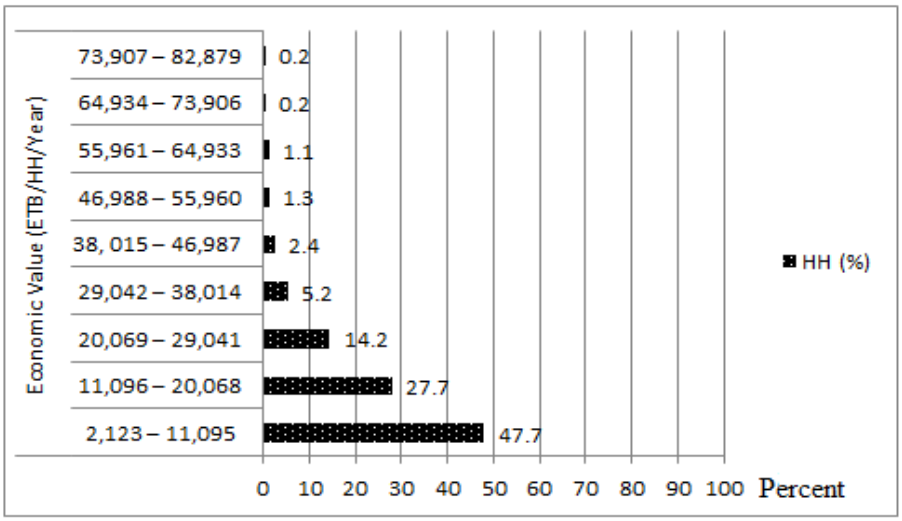


Figure 5.1: Distribution of Estimated Income (ETB) from Crop Harvest by Proportion (%) of HH of HRC in 2015/16 [**Source**: Own Design via Excel (2017) upon HH Survey Data (2016 - 2017)]

Economic value/income of crop produce for slightly less than half (47.7%) of the HH of HRC was about ETB 2,123 – 11,095 (US$ 98 – 514.5) in 2015/16, and it was about ETB 11,096 – 20,068 (US$ 514.6 – 932) and 20,069 – 29,041 (US$ 933 – 1,349.5) for 27.7% and 14.2% of them, respectively (Figure 5.1). Households whose estimated value of crop produce was ETB 29,042 – 82,879 (US$ 1,349.6 – 3,854.5) accounted only 10.4% in the whole HRC; in other words, the earning from crop harvest for nearly one-fourth (24.6%) of the HH of HRC was within US$ 933 – 3,854.5; and, it was less than US$ 933 for three-fourth (75.4%) of them (Figure 5.1).Gross income from crop harvest of HRC was estimated at US$ 695.3/HH for 2015/16 where the maximum income was about US$ 3,854.8 (ETB 82,879) (that is from LC) and the minimum was US$ 98.7 (ETB 2,123) (that is from MC).Per capita income from crop produce of HRC was US$ 139.1/person/year (Table 5.7a, Appendix III).

## 5.2 Cost and Net Economic Value (NEV) of Cropland Products of HRC

Measuring the NEV of nature through cropland services for human beings requires deducting cost of inputs used for cultivation (Freeman, 2003). Smallholders of HRC have spent money for wage labor, fertilizer, Water Pump Motor (WPM) for irrigation, and improved and unimproved seeds (of maize, onion, barley, wheat, bean, pea and potato) and seedlings (of banana, mango and apple) for the 2015/16 crop harvest. A higher cost was spent for daily laborers (51.9%) and inorganic fertilizers (26.5%) by

smallholders of the LC in 2015/16; whereas, the costs of rental WPM (9.2%), seeds (6.2%) and seedlings (6.2%) was limited. Wage labor expense by HH of the LC constituted 56.8% of the total labor cost of crop farming in HRC for 2015/16 production season (Table 5.2).

**Table 5.2: Cost (US$) of Farm Inputs Used by HH of HRC for 2015/16 Production Season**

| N0 | Input | Cost (US$), LC | | Cost (US$), MC | | Cost (US$), UC | | Cost (US$), HRC | |
|---|---|---|---|---|---|---|---|---|---|
| | | Amount | P (%) | Amount | P (%) | Amount | P (%) | Amount | P (%) |
| 1 | Labor (in #) | 7,084.8 | 51.9 | 1,778.4 | 24.4 | 3,604.7 | 38.3 | 12,467.9 | 41.1 |
| 2 | DAP (Kg) | 2,292.6 | 16.8 | 2,039.4 | 28.0 | 2,177.6 | 23.2 | 6,509.6 | 21.5 |
| 3 | Urea (Kg) | 1,320.6 | 9.7 | 1,388.9 | 19.1 | 1,447.5 | 15.4 | 4,157.0 | 13.7 |
| 4 | WPM (ND) | 1,252.4 | 9.2 | 0.0 | 0.0 | 0.0 | 0.0 | 1,252.4 | 4.1 |
| 5 | Seed (Kg) | 840.9 | 6.2 | 1,290.3 | 17.7 | 1,387.5 | 14.7 | 3,518.7 | 11.6 |
| 6 | Seedling (#) | 842.4 | 6.2 | 785.9 | 10.8 | 790.8 | 8.4 | 2,419.1 | 8.0 |
| | **Total** | **13,633.7** | **100.0** | **7,282.9** | **100.0** | **9,408.1** | **100.0** | **30,324.7** | **100.0** |

**Source:** Own Computation (2017) upon Table 5.9a, 5.9b, 5.9c and 5.9d, Appendix III [**WPM** = Water Pumping Motor; **ND** = Number of Days]

The inputs used by HH of the LC (except WPM) were also applied by inhabitants of the MC and UC of Hare in 2015/16. In the MC, farmers spent money for fertilizer (47.1%), labor (24.4%), seeds (17.7%) and seedlings (10.8%) used for production. A more or less equivalent expense was made for chemical fertilizer (38.6%) and wage labor (38.3%) in the UC of Hare; but, farmers' expense for the purchase of seeds (14.7%) and seedlings (8.4%) was relatively smaller in the Sub-catchment. Smallholders' tendency to use wage labor was limited in the MC and UC due to low income even if crop farming in these areas is more of labor intensive. Over three-fourth (76.3%) of the total input expense for crop harvest of 2015/16 season in HRC was spent for wage labor (41.1%) and fertilizer (35.2%); whereas, the cost of other farm inputs was relatively low (Table 5.2). Level of farm input expenditure of the LC was larger (45.0%) than the corresponding figure of the UC (31%) and the MC (24%) of Hare (Figure 5.2). The widely used wage labor (by 49.4% of the HH) and application of rental WPM for irrigation by 7.5% of them has uniquely increased the cost of farm inputs in the LC. The estimated NEV of nature through crop produce of the LC was also the largest (53%), followed by that of the UC (26.6%) and MC (20.4%) (Figure 5.2).

Average NEV from crop harvest (per/HH/year) was about US$ 893.1 (in LC), US$ 496.6 (in UC), US$ 445.0 (in MC) and US$ 630.1/HH/year in overall HRC (Table 5.7a, Appendix III).The per capita NEV from crop produce of the LC (US$ 178.6) was somewhat better; but, it was low for HH of the MC (US$ 89.0), UC (US$ 99.3) and overall HRC (US$ 126.0) (Table 5.7a, Appendix III).

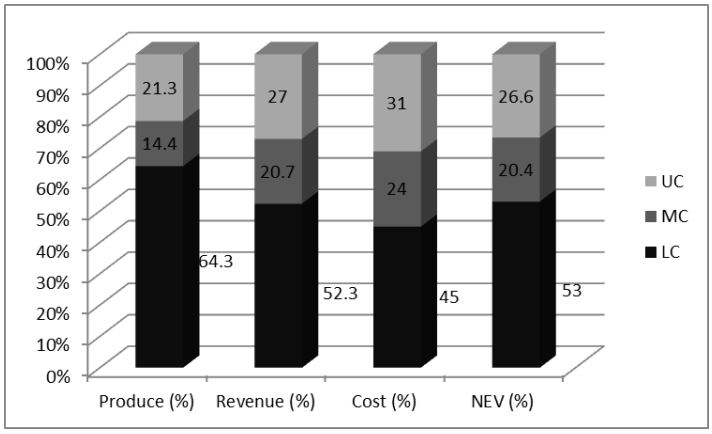


Figure 5.2: Share (%) of the LC, MC and UC within the Total Amount of Produce, Revenue/Income, Input Cost of and NEV from Crop Harvest of HRC in 2015/16 (**Source:** Own Design via Excel, 2017)

Variation of average NEV from crop harvest of HRC (among HH) was significant based on differences in "gender," "HH size," "farm size," "labor" and "fertilizer" used for cultivation in 2015/16 at 0.05 level (Table 5.1i, Appendix III); meaning, average earning of male-headed HH was significantly larger than that of females, and the figure was also significantly larger for HH having more "family" and larger "farm size," and for those who used more labor and fertilizer amount for the 2015/16 harvest. Variation of average income from crop harvest between the LC and MC of HRC (with a t-statistic of 8.39 and sig value of 0.000), and the LC and UC (having a t-statistic of 7.03 and sig value of 0.000) was also significant at 95%; but, it was not true for the MC versus the UC (Table 5.6a, b and c, Appendix III). Upon remote sensing data-based "valuation coefficient" of Costanza et al., (1997), cropland ESV of HRC was valued at US$ 1.362 million in 2015 (Table 5.5a, Appendix III).

## 5.3 Impact of Farm Inputs (Predictors) on Cropland Produce in HRC

Understanding impact of independent variables (farm inputs) on the dependent variable (crop produce) requires conducting a regression analysis; that is, farm inputs such as farm-size, oxen-power, labor, fertilizer, seedlings and seeds (utilized per/HH/year) were used to predict "crop produce" at Sub-catchment levels and overall HRC. Here, "seedling" is an input used for the growing of banana, mango, papaya, etc., perennials (at large) in LC, and for growing *enset* and apple in MC and UC.

Result of the regression analysis showed that 82.0% of the total crop harvest variation in LC was significantly predicted by the variation in the application of farm inputs (that is, farm size, oxen-power, labor, fertilizer, seedlings and seeds) among HH at 99% (Table 5.3a).

**Table 5.3a Model Summary of the Regression Analyses (at 99% Confidence Level)**

| N0 | Category | R | $R^2$ | Adjusted $R^2$ | SE of Estimate |
|---|---|---|---|---|---|
| I | LC | 0.905[a] | 0.820 | 0.806 | 1.79 |
| II | MC | 0.909a | 0.826 | 0.810 | 0.94 |
| III | 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) Dependent Variable:** Crop Produce**. Source:** Own Analysis via SPSS (version 20), 2017

Farm size, labor, fertilizer, seedlings and seeds used for 2015/16 production season have significantly predicted almost the same proportion (82.6%) of the total crop harvest variation among smallholders of the MC. Crop produce of the UC was better predicted by the farm inputs used for estimation than that of the LC and the MC. That is, 96% of the "produce" variation among HH of the UC was significantly predicted by differences in the amount of "seeds," "seedlings," "fertilizer," "labor" and "farm size" used (per/HH/year) in 2015/16 at 99% confidence interval (Table 5.3a).

**Table 5.3b ANOVA[a] of Crop Produce/Harvest by Smallholder Farmers (at 99% Confidence Level)**

| N0 | Catchment | Measure | Sum of Squares | df | $(Mean)^2$ | F | Sig. |
|---|---|---|---|---|---|---|---|
| I | LC | Regression | 1141.74 | 6 | 190.29 | 59.10 | 0.000[b] |
| | | Residual | 251.14 | 78 | 3.22 | | |
| | | Total | 1392.88 | 84 | | | |
| II | MC | Regression | 223.227 | 5 | 44.65 | 50.41 | 0.000[b] |
| | | Residual | 46.943 | 53 | 0.89 | | |
| | | Total | 270.169 | 58 | | | |
| III | UC | Regression | 842.937 | 5 | 168.59 | 260.14 | 0.000[b] |
| | | Residual | 34.996 | 54 | 0.65 | | |
| | | Total | 877.933 | 59 | | | |
| IV | HRC | Regression | 2334.75 | 5 | 466.95 | 171.77 | 0.000[b] |
| | | Residual | 557.29 | 205 | 2.72 | | |
| | | Total | 2892.04 | 210 | | | |

**Dependent Variable**: Total produce; **b) Predictors**: (Constant), Amount of seed, Level of seedling, Chemical fertilizer, Oxen power, Total labor, Farm size; (**Source**: Own Analysis via SPSS Version 20, 2017)

Variations in the amount of application of "seed," "seedling," "fertilizer," "labor" and "farm size" among smallholder farmers have also determined over three-fourth (78.2%) of the "produce" variation (among HH of the whole HRC) in 2015/16at 99% confidence level (Table 5.3a). Collinearity diagnosis was run to evaluate whether the correlation between Independent Variables (IV) inflates the variation explained on the dependent variable (crop harvest); and correlation coefficients (r) of all IV were less than 0.8

[Tables 5.1a, 5.1b (i), 5.1b (ii) and5.1c, Appendix III]. Collinearity effect, that is, variation inflated by regresses (IV) on the dependent one is significant if the coefficient (r) exceeds 0.8 (Quinn and Keough, 2001). Variance Inflation Factor (VIF) indicates how much variation of a dependent variable is inflated by predictors having very strong correlation (Gujarati, 2004). That is, if correlation (r) between regresses (IV) exceeds 0.8, it is difficult to use the variables (IV) for prediction of the dependent variable as the variation predicted becomes highly inflated or exaggerated.

Although "oxen power" was incorporated in the regression analysis of HRC, its effect was not significant (at a standard error of 0.01) since the use of this farm implement was restricted to the LC only. On the other hand, the F statistic (in ANOVA) tests whether the R square proportion of variance in the dependent variable accounted for by the predictors is zero (Moore et al., 2009; Penzer, 2011). However, the large F statistics and the low significance values ($0.000^{b}$) (both at Sub-catchment and overall study area levels) reveal that prediction of the dependent variable (crop produce) upon the five independent variables was statistically significant at a standard error of 0.01 (Table 5.3b).

**Table 5.3c: Beta Coefficients[a] and Collinearity Statistics of Predictors of Crop Harvest in LC**

| N0 | Predictor Variables | Beta Coefficients | | | Statistics | | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|
| | | Unstd. | Std. E | Std | T | Sig | Tolerance | VIF |
| 1 | (Constant) | -3.545 | 0.791 | - | -4.48 | 0.000 | - | - |
| 2 | Landholding 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 (kg/HH/Y) | 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. Dependent Variable**: Crop Produce/HH/Year; (**Source**: Own Analysis via SPSS, 2017). [Unstd. = Unstandardized; Std. E = Standard Error; Std. = Standardized]**(Significance Level is 99%);** Y = Year;

Result of the regression analysis revealed that the influence of "farm size" (0.351), "labor" (0.292), "seedlings" (0.198) and "fertilizer" (0.193) used (per/HH/year) on crop "produce" of the LC was significant at 99% confidence interval [where the respective significance values (0.000, 0.000, 0.000 and 0.003) of the variables were less than 0.01] (Table 5.3c). But, "oxen power" (having sig value of 0.19) and "seeds" (with sig value of 0.47) (used per/HH/year) showed no significant impact on "output" variation of the area (at 0.01 and 0.05 levels); this is because, over $3/4^{th}$ of the total harvest of the LC was obtained from agro-forestry (perennial) crops which rarely require "oxen power"-based land preparation

every season; that is why average "oxen-power" used in 2015/16 was 16 pairs per/HH and where amount of "seed" used (32.3 kg/HH/year) was also low, then(Table 5.12, Appendix III).

**Table 5.3d Beta Coefficients[a] and Collinearity Statistics of Predictors of Crop Harvest in 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 | Landholding 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. Dependent Variable**: Crop Produce/HH/Year; (**Source**: Own Analysis via SPSS, 2017). [Unstd. = Unstandardized; Std. E = Standard Error; Std. = Standardized]**(Significance Level is 99%)**; Y = Year

Amount of "harvest" from croplands of the MC was significantly impacted by "farm size" (0.228), "labor" (0.364), "seedlings" (0.235), "seeds" (0.200) and "fertilizer"(0.148) used (per/HH/year) at 99% confidence level (Table 5.3d). Standardized beta coefficients of the five predictors of crop harvest in the UC of Hare also reveal that the influence of the predictors on crop yield was statistically significant (see Table 5.3e below). "Labor" was the strongest significant predictor of crop harvest in the MC (0.364)and UC (0.316) of the study site in 2015/16.

**Table 5.3e: Beta Coefficients[a] and Collinearity Statistics of Predictors of Crop Harvest in 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 | Landholding 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. Dependent Variable**: Crop Produce/HH/Year; (**Source**: Own Analysis via SPSS, 2017). [Unstd. = Unstandardized; Std. E = Standard Error; Std. = Standardized]**(Significance Level is 99%); Y = Year;**

The coefficient of determination (0.960 or 96%) of crop harvest in the UC was somewhat inflated (Table 5.3a) due to the high values of Variance Inflation Factor (VIF)of landholding size (5.6), labor (7.9) and

seed (6.1) (Table 5.3e). Level of variance of an estimator inflated by the existence of multicollinearity problem is proved upon value of VIF (Gujarati, 2004). To evaluate whether multicollinearity effect (problem) exists between the explanatory variables used for predicting "crop harvest," values of VIF were computed for all Sub-catchments and overall HRC using SPSS. For instance, values of VIF for all the predictors such as landholding size (2.179), labor (2.959), fertilizer (2.091), seedlings (1.560)and seeds (1.720) used for the 2015/16 harvest by smallholder farmers of HRC were less than 10 (see Table 5.3f); and, VIF values of all predictors were also less than 10 in all the Sub-catchments (LC, MC and UC) (see Tables 5.3c, 5.3d and 5.3e). A VIF value greater than 10 is usually considered as a sign of significant multicollinearity problem in a regression model. Variance of a predictor increases as co-linearity increases, and in the limit it becomes infinity. Value of VIF becomes one (1) if there is no collinearity between regresses (predictors) (Gujarati, 2004).

Oxen power was not accounted in the regression analysis for the MC and UC since smallholder farmers do not often use this input (that is ox) for tillage and other farm activities in these parts of HRC, mainly, for two reasons: first, farm-plots were indicated to have not been suitable for oxen power-based farming due to high land fragmentation underlain by raising human population (according to an interviewee, 56); of course, the sideway-extents of adjacent farm-plots held by two or more HH look like different walk-ways for pedestrians when viewed at a distant. Second, most farmers have already ceased to rear oxen due to the shrinkage of grazing land (Assefa and Bork, 2016); in fact, grazing-land of HRC had also revealed a decline by 44.4% in 1976 – 2015 (Table 5.5b, Appendix III).

**Table 5.3f: Beta Coefficients[a] and Collinearity Statistics of Predictors of Harvest in 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 | Landholding 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 (kg/HH/Y) | 0.386 | 0.085 | 0.215 | 4.57 | 0.000 | 0.478 | 2.091 |
| 5 | Seedlings (#/HH/Y) | 0.111 | 0.022 | 0.209 | 5.14 | 0.000 | 0.641 | 1.560 |
| 6 | Seed (kg/HH/Y) | -0.055 | 0.011 | -0.215 | -5.02 | 0.000 | 0.582 | 1.720 |

**a. Dependent Variable**: Crop Produce/HH/Year; (**Source**: Own Analysis via SPSS, 2017). [Unstd. = Unstandardized; Std. E = Standard Error; Std. = Standardized] **(Significance Level is 99%);** Y = Year;

Crop harvest ("produce") of HRC was also significantly predicted by "landholding size" (0.406), "labor" (0.323), "fertilizer" (0.215) "seedlings" (0.209) and "seeds" (-0.215) used (per/HH/year) for 2015/16 harvest season (at 99% confidence level); that is, the p-value of all these predictor variables was 0.000 (that is less than 0.01) (Table 5.3f). "landholding size" (ha/HH) (0.406) and "labor" (0.323) used (per/HH/year) were the 1st and 2ndstrongest significant predicators of crop harvest from the whole HRC in 2015/16 as these variables have larger standardized beta coefficients (Table 5.3f). Beta coefficient of "seeds" used (kg/HH/year) by smallholders of HRC was negative (-0.215); this is because, amount of seeds (32.3 kg/HH/year) applied by HH of the LC was limited despite its high average crop harvest (35.4 Quintal/HH/year) in 2015/16; that is, where over three-fourth of the produce was obtained from agro-forestry crops-requiring seedlings as direct inputs (instead of seeds). Farmers' use of seeds (for annual crops) is often limited where cultivation is dominated by perennials like the LC. But, amount of seeds sown by farmers of the MC (82.4 kg/HH) and UC (62.2 kg/HH) (Table 5.12, Appendix III) was high even if average crop harvest (Quintal/HH/year) of the respective Sub-catchments (10.3and 13.1 quintal) was low/small (Table 5.7a, Appendix III).

## 5.4 Discussion

Value of provisioning cropland products of HRC was quantified for 2015/16, where the level of produce of the LC was slightly less than two-fold of the harvest from the MC plus UC of HRC. The deep, plain, alluvial (fluvial), neutral to slightly alkaline fertile soils having rich supply of primary nutrients (Glendinning, 2000; Yechale, 2012) and better farm size (0.60 ha/HH), have favored better crop harvest (Abren, 2007) from the LC; the low level of crop harvest of the MC and UC was due to utilization of land for similar crops for centuries (Abren, 2007; Assefa and Bork, 2016), landscape steepness, severe erosion, acidic and poor soils, inadequate conservation practices (Yechale, 2012), and smaller farm size per/HH (that is 0.38 ha in MC and 0.45 ha in UC). Farming was practiced on steep ($15 – 30^0$) to very steep plots (over $30^0$) (FAO, 1990; Abren and Abera, 2012) constituting 70% of the sample sites from both the MC and UC where gradient was measured (Yechale, 2012); and, where about 70 – 86.3% of the existing land uses and soil conservation measures, according to Yechale (2012), did not match to those recommended in the "treatment-oriented capability classification" – a model applicable in topographically rugged areas like the MC and UC of Hare (Belay, 2003).

Estimated average gross income (US$ 695.3) and NEV (US$ 630.1) from crop harvest of HRC (in 2015/16) was smaller in comparison to the net value of harvest(US$ 1157 per/HH) from "Bale Mountain

Ecosystem"- reported some years ago (Watson, 2007). Difference in NEV of products between HRC and Bale might have originated from disparities in the type of crops grown, input costs considered (Shackleton et al., 2001), price of products, and currency difference (that is, ETB to US$) between the study periods. For instance, labor, fertilizer, WPM (for irrigation), seed and seedling costs were accounted in the estimation of NEV of crop products of HRC; whereas, cost of most inputs were assumed negligible in the case of "Bale Mountain Ecosystem" (Watson, 2007). Where labor cost is not accounted in measuring net values, estimated NEV of crop harvest is thought to rise by 12 - 40% (Shackleton et al., 2001). Gross value (US$ 695.3) of crop harvest of HRC was larger than the figure (US$ 679/HH/year) obtained from Serengeti area of Tanzania (Emerton and Mfunda, 1999) and the value reported (US$ 443/HH/year) from an agro-pastoral rural area of South Africa (Dovie et al., 2003; O'Farrell et al., 2011). Besides, mango, papaya, banana, avocado, moringa, etc., perennials of the LC of Hare provide services beyond products harvested on-site, such as controlling climate and air quality via carbon sink (Swinton et al., 2007; Sthapit and Scherr, 2012), maintaining soil biodiversity, fertility and yield **(**Nelson et al., 2009; Norris et al., 2010; Park et al., 2010), controlling water/moisture supply and supporting pollinators (Zhang et al. 2007; Norris et al., 2010; Robertson et al., 2014), etc.

# Chapter Six

# Values of Selected Provisioning Services of Forest/Woodland in HRC

## 6.1 Level and Distribution of Fuel-Wood (Firewood and Charcoal) Consumption

Forest provides multiple goods and services to people, ranging from local through regional to global scale benefits (MEA, 2005). Forest, riverine vegetation, woodland and/or bush-land resources (Table 6.8a, Appendix IV) are the main sources of diverse services for HH of HRC (Table 4.6, Appendix II). The interest here, however, is on the consumption and economic value of fuel-wood (firewood and charcoal) and timber products.

Table 6.1a Distribution of Annual Firewood Consumption (kg/HH/Year) by HH of HRC, 2015/16

| N0 | FW (kg/HH/Year) | LC | | MC | | UC | | HRC | |
|---|---|---|---|---|---|---|---|---|---|
| | | N0 | P (%) | N0 | P (%) | N0 | P (%) | N0 | P (%) |
| **1** | 120 – 692 | 16 | 9.2 | 6 | 4.5 | 14 | 8.9 | 36 | 7.7 |
| **2** | 693 – 1265 | 51 | 29.3 | 27 | 20.2 | 40 | 25.5 | 118 | 25.4 |
| **3** | 1266 – 1838 | 52 | 29.9 | 46 | 34.3 | 48 | 30.6 | 146 | 31.4 |
| **4** | 1839 – 2411 | 35 | 20.1 | 36 | 26.9 | 31 | 19.7 | 102 | 21.9 |
| **5** | 2412 – 2984 | 19 | 10.9 | 18 | 13.4 | 21 | 13.4 | 58 | 12.5 |
| | Sub-total | 173 | 99.4 | 133 | 99.3 | 154 | 98.1 | 460 | 98.9 |
| | No response | 1 | 0.6 | 1 | 0.7 | 3 | 1.9 | 5 | 1.1 |
| | **Total** | **174** | **100** | **134** | **100** | **157** | **100** | **465** | **100** |

Source: Own Analysis upon Field Survey Data, 2016/17

As it is illustrated in Table 6.1a, about 98.9% of the HH of HRC use firewood as one of the sources for domestic energy consumption; and, the estimated amount of firewood utilization was in the range of 120 – 2,984 kg/HH/year in 2015/16. Consumption level of this energy source was estimated at 693 – 2,411 kg/HH/year for over three-fourth of the HH of the LC (79.3%), MC (81.4%), UC (75.8%) and the whole HRC (78.7%). The large F statistics (22.18) and its significance value (0.000) revealed that difference in average amount of firewood consumption (annually) between male and female-headed households of HRC was significant at 95% confidence interval (Table 6.4a, Appendix IV); that is, the mean consumption of the fuel-product by male-headed HH (1677.5kg) was significantly larger than that of the female-headed counterparts (1370.8kg), annually (Table 6.7b**,** Appendix IV).

"HH size" and "social (income) status" is assumed to influence the demand for home energy consumption and level of acquisition of fuel products from forest and other sources. Variation in the amount of firewood consumption (kg/HH/year) among residents was statistically significant at 95% confidence level based on difference in family (HH) size; this holds true for HH of the LC (with 'F' statistic of 18.298 and sig value of 0.000), the UC (having F value of 5.186 and sig value of 0.002) and the whole HRC (where the F statistics was 9.023 and its sig value was 0.000) (Table 6.4c, Appendix IV ). Similarly, variation in average firewood use among HH of HRC was also significant upon income difference from crop harvest (where the F value was 8.43 and its sig value was 0.000) (Table 6.7b, Appendix IV). That is why, in the whole HRC, level of firewood consumption was positively correlated with "HH size" ($0.215^{**}$) at a standard error of 0.01; it was also positively associated with amount of "crop harvest" ($0.368^{**}$) and income ("crop value") from crop harvest (0.364**) at 99% confidence level (Table 6.5b); meaning, the level of consumption of this energy product was higher for the inhabitants with larger family size and also, for those who had obtained better yield and income from crop harvest in 2015/16; whereas, it was lower for HH having smaller family size and lower yield and income from cropland ecosystem.

Average level of firewood consumption was estimated at 1,518.9 kg, 1,694.2 kg and 1,570.6 kg for the rural residents of the LC, MC and UC in 2015/16, respectively; and, the figure was 1,586.9 kg in the whole study area (Table 6.3a). Inferential statistics based comparison was also carried out to evaluate whether there was a significance variation in average firewood consumption between the three Sub-catchments (the LC, MC and UC). The result revealed that differences in mean firewood consumption of HH between the LC and MC [with t-value is -3.224 and sig (2-tailed) value is 0.001], and the MC and UC [having t-value of 1.975 and sig (2-tailed) value of 0.048] were statistically significant at 95% confidence level. However, the variation in the mean level of consumption of this fuel product between residents of the LC and UC was not significant at 0.05 (Table 6.4b, Appendix IV). Meaning, average firewood consumption by HH of the MC was significantly larger than that of the LC and UC. The relatively low average firewood use by HH of the LC was due to reliance of the dwellers on diverse energy sources such as charcoal (51.1%), electric and/or solar cell power (52.9%), natural gas (35.6%), etc., other than firewood; and also, where hydro-power was exceptionally used in the Sub-catchment (that is, the LC) (Table 6.5a, Appendix IV). In fact, the hot local climate condition of the LC (where mean annual temperature is $24^0$C) might be among the reasons for lower level of firewood energy consumption by HH of the Sub-catchment.

Charcoal is the other product used for home energy consumption by residents of HRC. Results of the study about the level of consumption of this fuel-product are organized below (Table 6.1b).

**Table 6.1b Distribution of Annual Charcoal Consumption (kg/HH/year) by HH of HRC, 2015/16**

| N0 | Charcoal (kg/HH/Year) | LC | | MC | | UC | | HRC | |
|---|---|---|---|---|---|---|---|---|---|
| | | N0 | P (%) | N0 | P (%) | N0 | P (%) | N0 | P (%) |
| **1** | 12 – 79 | 14 | 8.0 | 1 | 0.8 | 4 | 2.5 | 19 | 4.1 |
| **2** | 80 – 147 | 31 | 17.8 | 4 | 3.0 | 8 | 5.1 | 43 | 9.2 |
| **3** | 148 – 215 | 24 | 13.8 | 3 | 2.2 | 11 | 7.0 | 38 | 8.2 |
| **4** | 216 – 283 | 20 | 11.5 | 2 | 1.5 | 7 | 4.5 | 29 | 6.2 |
| | Sub-total | 89 | 51.1 | 10 | 7.5 | 30 | 19.1 | 129 | 27.7 |
| | No response | 85 | 48.9 | 124 | 92.5 | 127 | 80.9 | 336 | 72.3 |
| | **Total** | **174** | **100** | **134** | **100** | **157** | **100** | **465** | **100** |

Source: Own Analysis upon Field Survey Data, 2016/17

Unlike firewood, charcoal was consumed by a limited proportion (27.7%) of the HH in the Catchment. Annual amount of charcoal fuel use (that is, 12 – 283 kg/HH/year)by inhabitants of HRC was also limited (Table 6.1b) as production of this energy source is illegal. But, households who were using this product for domestic energy consumption (in 2015/16) were relatively larger (51.1%) in the LC than that of the UC (19.1%) and the MC (7.5%). In the LC, consumption of this fuel source was 12 – 79, 80 – 147, 148 – 215 and 216 – 283 kg/HH/year for 8%, 17.8%, 13.8% and 11.5% of the HH, respectively; and, households with the respective level of charcoal consumption accounted 4.1%, 9.2%, 8.2% and 6.2% in the whole HRC. "HH size" difference-based variation in amount of charcoal consumption by HH of the LC was not statistically significant at 95% since its F statistic (0.351) was small and its sig value was greater than 0.05 (that is, 0.789); and this also holds true for the whole study area (HRC) where the significance value was 0.906 (Table 6.4c, Appendix IV).

The estimated charcoal energy consumption (kg/HH/year) by residents of the LC (151.7kg), the MC (154.3kg), the UC (161.1kg) and the overall HRC (154.1 kg) was too limited in 2015/16 (Table 6.3a). This was because; charcoal production (according to an interviewee, 47) is carried out largely for cash (rather than for home use) as it is an activity by the poor who are targeted to generate income by supplying the product at market centers in nearby urban areas. Here, independent sample test was run so as to appraise whether there was a significant variation in average charcoal use between the LC, MC and UC of HRC; that is, the result revealed that the variation was not significant at a standard error of 0.05 (Table 6.4c, Appendix IV); this was due to the limited proportion of households who were using charcoal in the

MC (7.5%) and UC (19.1%) of Hare. The estimated average fuel-wood (firewood and charcoal) consumption by residents of HRC was about 1,630.1 kg/HH in 2015/16; the figure was the largest for HH of the MC (1,705.8 kg), followed by that of the UC (1,602.0 kg) and the LC (1596.9 kg). Level of firewood and charcoal consumption by residents of HRC was estimated at 326 kg/person/year; and, the per capita fuel-products' consumption of the LC (319.4kg), the MC (341.2kg) and the UC (320.4kg) was also small (Table 6.3a).

Generally, residents of HRC acquire firewood, charcoal and timber products (for construction) from diverse species of trees. Trees such as acacia (*albida*), desert-date (*balanites aegyptiaca*), flamboyant (*delonic regia*), bitter-leaf (*vernonia amygdalina*), *moringa oleifera, woybeta, eucalyptus camaldulensis (key-bahir-zaf), acacia senegal (kontir), mangifera indica*, avocado (*persea Americana*), etc., are important sources of fuel-wood and timber in LC of Hare (Table 6.11a, Appendix IV). Whereas, these products are generated from croton (*croton macrostachyus*), flat-top acacia (*acacia abyssinica*), olive (*cuspidate olea africana*), *tid* (*juniperus procera*), cypress (*cupressus lusitanica*) or *yeferenji-tid*, hop-bush (*dodonaea viscosa*), bitter-leaf (*vernonia amygdalina*), *embus* (*allophylus abyssinicus*), *koshim* (*dovyalis abyssinica*), *eucalyptus citriodora (nech-bar-zaf)*, mountain bamboo (*arundinaria alpine*), reed-grass (*arundo donax*), and other tree species which are growing in the MC and UC of the study area (Table 6.11b, Appendix IV).

## 6.2 Economic Value of Fuel-Wood and Timber Products

Economic values of firewood and charcoal products of nature were measured or estimated based on prices at local markets; that is, average firewood price was about US$ 2.19 per/shoulder in 2015/16; and, a sack of charcoal was exchanged at US$ 3.86 in the study area (Table 6.3a). The results about economic values of these energy products of nature were organized in Table 6.2a and 6.2b below. As it is displayed in Table 6.2a, the maximum estimated economic value of firewood used by inhabitants of HRC did not exceed about US$ 327 (ETB 7,066) per/HH/year in 2015/16. Firewood related income was estimated at US$ 76 – 138 (ETB 1,639 – 2,995), US$ 139 – 201 (ETB 2,996 – 4,352) and US$ 202 – 264 (ETB 4,353 – 5,709) per/HH/year for 29.3%, 29.9% and 20.1% of the HH in the LC in 2015/16, respectively; and, the respective amount of service value was earned by 25.5%, 30.6% and 19.7% of the HH of the UC; this means, the annual value of this energy product for over three-fourth of the HH of the LC (79.3%) and the UC (75.8%) was about US$ 76 – 264 (ETB 1,639 – 5,709). Residents of the MC who had enjoyed an estimated firewood service value of US$ 76 – 138 (ETB 1,639 – 2,995), US$ 139 – 201 (ETB 2,996 –

4,352) and US$ 202 – 264 (ETB 4,353 – 5,709) per/HH/year accounted 20.2%, 34.3% and 26.9%, respectively, that is, who were over four-fifth (81.4%) of the total HH.

**Table 6.2a Distribution of Firewood Value [ETB (US$)/HH/Year] among HH of HRC, 2015/16**

| N0 | Value (per/HH/Year) | | LC | | MC | | UC | | HRC | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ETB | US$ | N0 | P (%) | N0 | P (%) | N0 | P (%) | N0 | P (%) |
| **1** | 282 – 1638 | 13 – 75 | 16 | 9.2 | 6 | 4.5 | 14 | 8.9 | 36 | 7.7 |
| **2** | 1639 – 2995 | 76 – 138 | 51 | 29.3 | 27 | 20.2 | 40 | 25.5 | 118 | 25.4 |
| **3** | 2996 – 4352 | 139 – 201 | 52 | 29.9 | 46 | 34.3 | 48 | 30.6 | 146 | 31.4 |
| **4** | 4353 – 5709 | 202 – 264 | 35 | 20.1 | 36 | 26.9 | 31 | 19.7 | 102 | 21.9 |
| **5** | 5710 – 7066 | 265 – 327 | 19 | 10.9 | 18 | 13.4 | 21 | 13.4 | 58 | 12.5 |
| | Sub-total | - | 173 | 99.3 | 133 | 99.3 | 154 | 98.1 | 460 | 98.9 |
| | No response | - | 1 | 0.7 | 1 | 0.7 | 3 | 1.9 | 5 | 1.1 |
| | **Total** | **-** | **174** | **100** | **133** | **100** | **157** | **100** | **465** | **100** |

Source: Own Analysis upon Field Survey Data, 2016/17

In general, the economic value of firewood consumption in the whole HRC was estimated at US$ 139 – 327 (ETB 2,996 – 7,066) for almost two-third (65.8%) of the HH in 2015/16 (Table 6.2a). Level of firewood service value of nature showed significant variation among HH of the LC, UC and overall HRC at 95% level of confidence upon difference in "HH size;" that is, where the F statistics and significance values (in brackets) of the respective areas were 18.298 (0.000), 5.186 (0.002) and 9.023 (0.000); but, its variation was not significant for residents of the MC (at 95%) since the F statistics was 0.690 and its sig value was 0.560 (Table 6.4c, Appendix IV).

Average economic value of firewood product (per/HH/year) was the largest (US$ 186.5 or ETB 4,009.8) for HH of the MC, followed by estimated value of the UC (US$ 172.9 or ETB 3,717.4) and the LC (US$ 167.2 or ETB 3,594.8) per/HH/year; and the figure was about US$ 174.7 (ETB 3,756.1) per/HH/year for the whole Catchment. Differences in the mean value of firewood service between HH of the LC and MC [having t-value of -6.51 and sig (2-tailed) value of 0.000] and the MC and UC [with t-value of 2.02 and sig (2-tailed) values of 0.044] were significant at 95% confidence interval (Table 6.4b, Appendix IV). The relatively larger average value of firewood service (earned by HH of the MC and UC) has emanated from the greater dependence of residents of these Sub-catchments on firewood, lack of electric power service (unlike the LC) and also, the use of charcoal fuel by limited HH proportions in the MC (7.5%) and UC (19.1%) of Hare (Table 6.2b). The relatively cold micro-climate condition of the MC and UC

(where the mean annual temperature was $16.8^0$C)(MAE, 2016) could also contribute to the higher level of home energy consumption in these areas; in this regard, an interviewee, 47, stated that firewood consumption by residents of the MC and UC often increases during the rainy seasons (March to May/June and August/September to November) as the fuel product is required to overcome the impact of cool weather (in addition to other HH energy requirements).

**Table 6.2b Distribution of Charcoal Value[ETB (US$)/HH/Year]among HH of HRC, 2015/16**

| N0 (#) | Value (per/HH/Year) | | LC | | MC | | UC | | HRC | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ETB | US$ | N0 | P (%) | N0 | P (%) | N0 | P (%) | N0 | P (%) |
| **1** | 041 – 289 | 02 – 14 | 14 | 8.0 | 1 | 0.8 | 4 | 2.5 | 19 | 4.1 |
| **2** | 290 – 538 | 15 – 26 | 31 | 17.8 | 4 | 3.0 | 8 | 5.1 | 43 | 9.2 |
| **3** | 539 – 787 | 27 – 38 | 24 | 13.8 | 3 | 2.2 | 11 | 7.0 | 38 | 8.2 |
| **4** | 788 – 1036 | 39 – 50 | 20 | 11.5 | 2 | 1.5 | 7 | 4.5 | 29 | 6.2 |
| | Sub-total | - | 89 | 51.1 | 10 | 7.5 | 30 | 19.1 | 129 | 27.7 |
| | No response | - | 85 | 48.9 | 124 | 92.5 | 127 | 80.9 | 336 | 72.3 |
| | **Total** | **-** | **174** | **100** | **134** | **100** | **157** | **100** | **465** | **100** |

Source: Own Field Survey, 2015/16

Estimations were also carried out so as to understand the financial benefits of charcoal service for inhabitants of HRC (Table 6.2b). In comparison with firewood service, the benefit of charcoal seems limited as its maximum estimated economic value did not exceed about US$ 50 (ETB 1,036) annually, and as it was used by only slightly over one-fourth (27.7%) of the HH in HRC. However, this HH energy source was more significant for inhabitants of the LC where its value was estimated at US$ 02 – 14 (ETB 041 - 289), 15 – 26 (ETB 290 - 538), 27 – 38 (ETB 539 - 787) and 39 – 50 (ETB 788 – 1,036) per/year for 8%, 17.8%, 13.8% and 11.5% of the HH in 2015/16, respectively. Charcoal was used by limited proportion (7.5%) of the HH in the MC of Hare; that is, where the value of this fuel product was about US$ 2 – 26 (ETB 41 - 538) and US$ 27 – 50 (ETB 539 – 1,036) per annum for the respective 3.8% and 3.7% of the HH in the MC; and, households of the UC who have earned the respective economic value from charcoal accounted 7.6% (US$ 2 – 26) and 11.5% (US$ 27 – 50) in 2015/16. About 13.3% of the HH of HRC were found to have enjoyed an estimated value of about US$ 2 – 26 (ETB 41 - 538) via charcoal use in 2015/16, and the earning was estimated at US$ 27 – 50 (ETB 539 – 1,036) for 14.4% of the HH, then.

The estimated average value of charcoal consumption (per/HH/year) for residents of the LC (US$ 25.8 or ETB 554.7), the MC (26.2 or ETB 563.3), the UC (27.4 ETB 589.1) and the whole HRC (US$ 26.2 or ETB 563.3) was also very limited during 2015/16.

**Table 6.3a Level of Consumption (kg), Prices and Values (US$) of Fuel-Wood Productsby HH of HRC, 2015/16**

| Product | N0 | Attributes of the Products | LC | MC | UC | HRC |
|---|---|---|---|---|---|---|
| Firewood | 1 | Mean FW consumption (kg/HH/Year) | 1518.9 | 1694.2 | 1570.6 | 1586.9 |
| | 2 | Mean FW price: US$/Shoulder (US$/kg) | 2.19 (0.11) | 2.19 (0.11) | 2.19 (0.11) | 2.19 (0.11) |
| | 3 | Mean FW value (US$/HH/Year) | 167.2 | 186.5 | 172.9 | 174.7 |
| | 4 | Total FW value (US$/Year) | 28,925.6 | 24,804.5 | 26,626.6 | 80,356.7 |
| | 5 | HH who were using FW energy | 173 | 133 | 154 | 460 |
| Charcoal | 1 | Mean charcoal consumption (kg/HH/year) | 151.7 | 154.3 | 161.1 | 154.1 |
| | 2 | Mean charcoal price: US$/Sack (US$/kg) | 3.86 (0.17) | 3.86 (0.17) | 3.86 (0.17) | 3.86 (0.17) |
| | 3 | Mean charcoal value (US$/HH/Year) | 25.8 | 26.2 | 27.4 | 26.2 |
| | 4 | Total charcoal value (US$/Year) | 2,292.9 | 262.0 | 820.9 | 3,374.8 |
| | 5 | HH who were using charcoal for HH energy | 89 | 10 | 30 | 129 |
| Both | 1 | Mean FW and charcoal consumption (kg/HH/year) | 1596.9 | 1705.8 | 1602.0 | 1630.1 |
| | 2 | Per capita FW and charcoal use (kg/person/year) | 319.4 | 341.2 | 320.4 | 326.0 |
| | 3 | Average FW and charcoal value (US$/HH/year) | 180.5 | 188.5 | 178.2 | 182.0 |
| | 4 | Per capita FW and charcoal value (US$/person/Yr) | 36.1 | 37.7 | 35.6 | 36.4 |
| | 5 | HH who were using FW and charcoal energy | 173 | 133 | 154 | 460 |
| | 6 | Average HH size | 5 (5.4) | 5 (5.2) | 5 (5.1) | 5 (5.3) |

Source: Own Computation (2017) upon Own HH Survey Data (2016 – 2017)

Since HH of the LC who use charcoal for home energy consumption were larger in proportion, one-way ANOVA was conducted to evaluate whether there was a significant variation in the economic value of this energy use among HH of HRC upon differences in HH size; and, the result revealed that the variation was not statistically significant at 95% (where the F statistics was 0.440 and the sig value was 0.725) (Table 6.4d, Appendix IV). To sum up, the level of economic benefit from charcoal service of nature was limited since 72.3% of the inhabitants of HRC revealed that they were not consuming the fuel product for home use in 2015/16; this could be due to the limited tradition of utilizing charcoal for home fuel generation by rural HH and/or due to failure of sample households to provide genuine responses about whether they use this product for home energy consumption. In fact, anyone who travels to and from Arba-Minch - Addis Ababa (crossing the LC of Hare) may suddenly observe sacks of charcoal ready for sale for passengers and truck drivers; this happens even if (according to a Development Agent) production

of charcoal from common resources is restricted by law. Of course, illegal nature of charcoal production could be the basic reason for sample households' speculation to give appropriate evidences about level of consumption of the fuel product.

Result of the study about the estimated value (income) distribution [in ETB (US$)/HH] from both firewood and charcoal services by HH of HRC (2015/16) is illustrated below (Figure 6.1). As it can be observed from Figure 6.2 above, the maximum economic value of firewood and charcoal products for inhabitants of HRC did not exceed about US$ 342 (ETB 7,319), and the minimum was about US$ 13 (ETB 282) per/HH/year. The estimated firewood and charcoal services value of the relatively larger proportion (29.5%) of the HH of HRC was within US$ 123 – 177 (ETB 2,628 – 3,800). And, about 21.5%, 7.3%, 21.9% and 13.1% of the HH of Hare were found to earned the respective estimated values of about US$ 68 – 122 (ETB 1,455 – 2,627), US$ 178 – 232 (ETB 3,801 – 4,973), US$ 233 – 287 (ETB 4,974 – 6,146) and US$ 288 – 342 (ETB 6,147 – 7,319) per/HH/year (Figure 6.1).

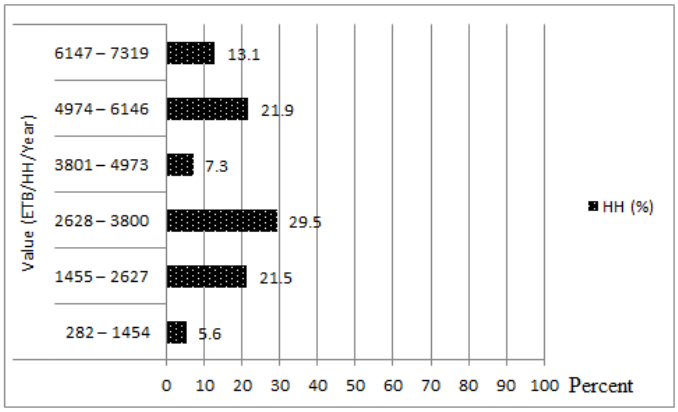


Figure 6.1 Distributions of Firewood and Charcoal Value (ETB/HH/Year) upon Proportion (%) of HH of HRC, 2015/16 (Source: Own Design via Excel, 2017)

Variation in the amount of earning from firewood and charcoal services revealed significant variation among HH of HRC upon difference in "HH size" (with F statistics of 8.931 and sig value of 0.000), and gender difference based variation of income from the fuel-products was also significant at 95% (where the F statistics of 21.35 and sig value 0.000) (Table 6.4a, Appendix IV). In other words, households having larger family size enjoy higher average earning from firewood and charcoal services than those with smaller HH size; and, the average economic value of both energy services of male-headed HH (US$ 197.3 or ETB 4,240.8) of HRC significantly exceeds that of the female-headed ones (US$ 154.7 or ETB 3,326.1) in the period accounted by the study (2015/16) (Table 6.7b, Appendix IV). Average value of firewood and charcoal services for rural HH of HRC was estimated at US$ 182 (ETB 3,913); this figure

was the largest (US$ 188.5 or ETB 4,052.8) for dwellers of the MC, and it was followed by that of the LC (US$ 180.5 or ETB 3,880.8) and the UC (US$ 178.2 or ETB 3,831.3)/HH/year (Table 6.3a). The per capita value (US$/person/year) of both fuel-products for residents of the LC (36.1), MC (37.7), UC (35.6) and overall HRC (36.4) was low (Table 6.3a).

On the other hand, "value coefficients" of forest, riverine vegetation, woodland and bush/shrub for the production of raw materials like lumber/timber (for construction), fuel-wood, fodder, etc., products were about US$ 138, 138, 138 and 25 per/ha/year, respectively (Costanza et al., 1997); and, area size of the respective resources was 609.2ha, 1124.8ha, 2647.9ha and 2905.6ha in 2015 (Table 6.8a, Appendix IV). Thus, forest, riverine vegetation, woodland and bush/shrub value of HRC for the extraction of consumptive services such as timber, fuel (firewood and charcoal), fodder, etc., was estimated at US$ 84,069.6, 155,222.4, 365,410.2 and 72,640, respectively. Thus, the sum value of forest, riverine vegetation, woodland and bush/shrub of the Catchment for the production of these services became about US$ 677,342.2 for the year 2015.

## 6.3 Discussion

The average fuel-wood(firewood and charcoal) consumption (1,630.1 kg/HH/year) by inhabitants of HRC was by far smaller in comparison with results of other studies (Appasamy, 1993; Metz, 1994; Pimentel et al., 1997a); that is, Appasamy (1993) indicated that wood consumption required for cooking and heating in India was about 912 - 1,200 kg/individual/year; and, another study revealed that the per capita consumption of fuel-wood was estimated at 846 kg/individual/year in Nepal (Metz, 1994). A level of fuel-wood utilization of about 0.7 ton or 700 kg/person/year was also reported by another study (Pimentel et al., 1997a). However, the 2015/16 per capita fuel-wood (firewood and charcoal) consumption (326 kg/individual/year) of HRC was too low.

The progressive shrinkage of forest, woodland, riverine vegetation and bush/shrub, and dwindling supply of their services is among the basic reasons for the low level of fuel products' consumption in HRC, which (in turn) is the consequence of increasing human population (Assefa and Bork, 2016), farming expansion, frequent exploitation of fuel-products and construction materials, expansion of settlement and infrastructure (Belay, 2002; Yechale, 2012). For instance, forest and woodland of HRC had shrunk from 2,835.4 to 609.2 ha and 6,842.3 to 2,647.9 ha within 1967 – 2015, respectively; and, the overall service value of forest had declined by US$ 2,172,000 (from US$ 2,758,000 to 586,000) and that of woodland

get also dwindled by US$ 1,270,000 (from US$ 2,069,000 to 799,000) in four-five decades (Table 6.8a and 6.8b, Appendix IV). Besides, reliance of HH of HRC on different energy sources like hydro-power (19.8% HH of HRC – who were 52.9% of the HH in LC), gasoline (61.3%), solar cell energy (29.7%), animal dung (4.7%) and crop residue (4.3%) might have contributed for the low level of fuel-product consumption (Table 6.5a, Appendix IV). Average value of fuel-wood service for rural HH of HRC (US$ 182 per/HH/year) was slightly higher than the value of same service (US$ 165) for rural HH of Bale Mountain Ecosystem (Southeast Ethiopia) (Watson, 2007).

# Chapter Seven

# Distribution of Income from Crop and Fuel-Wood Products of HRC

Economic values of the "products of croplands" and "fuel-wood services of forest/woodland" of HRC have been presented in "Chapter Five" and "Chapter Six," respectively. In this chapter, summarized results are presented about the gross income (US$) and Net Economic Value (NEV) derived from both crop harvest and fuel-wood services of nature by rural residents of HRC.

## 7.1 Distribution of Income among HH of the LC, MC and UC of HRC

Cropland and fuel-wood provisioning products are among the major services generated by residents of HRC, Southern Ethiopia. Thus, the emphasis, under this sub-heading, is on the distribution of gross income and NEV of crop and fuel-wood products of nature by HH of the LC, MC and UC of Hare.

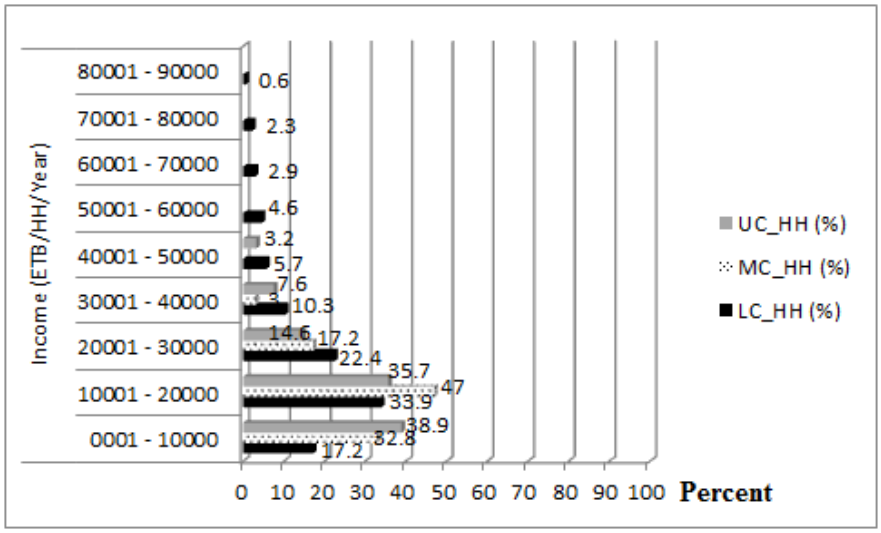


Figure 7.1a Distribution (%) of HH of the LC, MC and UC upon Level of Estimated Income from Crop Harvest and Fuel-Wood (Firewood and Charcoal) Services in 2015/16

Figure 7.1a illustrates clear differences between the LC, MC and UC in the amount of income (ETB) derived from crop harvest and fuel-wood (firewood and charcoal) products in 2015/16. The maximum income from both sets (crop and fuel-wood) of products did not exceed ETB 50,000 (US$ 2,325.5) in the UC and ETB 40,000 (US$ 1,860.4) in the MC. Households of the UC (38.9%) who earned about ETB 10,000 (US$ 465.1) and smaller were larger than proportion of HH of the MC (32.8%) and the LC (17.2%) who got the same level of income from the products. Households who generated an estimated

gross income of about ETB 10,001 – 20,000 (US$ 465.15 – 930.2) were 47% in MC, 35.7% in UC and 33.9% in LC of Hare. The estimated income generated from crop and fuel-wood products was about ETB 20,001 – 30,000 (US$ 930.25 – 1,395.30) for 22.4%, 17.2% and 14.6% of the HH of the LC, MC and UC in the study period, respectively. Proportion of HH of the LC (16%) who derived an estimated income of ETB 30,001 – 50,000 (US$ 1,395.35 – 2,325.50) from the provisioning products was by far larger than HH of the UC (10.8%) and the MC (3%) who enjoyed the same level of earning in 2015/16. Again, about one-tenth (10.4%) of the HH in LC generated an estimated income within ETB 50,001 – 90,000 (US$ 2,325.55 – 4,185.90) annually, but none of the HH in the MC and UC obtained an earning that exceeds ETB 50,000 (US$ 2,325.50) from crop and fuel-wood products (Figure 7.1a above). Anyway, nearly four-fifth (79.8%) of the HH in MC, three-fourth (74.6%) of the HH in UC and slightly over half (51.1%) of the HH in LC obtained an estimated gross income of US$ 930.2 and smaller from crop and fuel-wood products in 2015/16 (Figure 7.1a above). In other words, households who derived an estimated income of ETB 20,001 – 40,000 (US$ 930.25 - 1,860.40) were only about one-fifth (20.2%) in the MC; and, only one-fourth (25.4%) of the HH in the UC earned ETB 20,001 – 50,000 (US$ 930.25 - 2,325.50).

Table 7.1 Average Income Derived from Crop and Fuel-Wood Products by Male-Headed and Female-Headed HH of HRC in 2015/16 (that is, variation is significant at 95% confidence level)

| N0 | Catchment | Gender | Average Income | | N0 of HH |
|---|---|---|---|---|---|
| | | | ETB | US$ | |
| 1 | Lower Catchment | Male | 26,555.7 | 1,235.2 | 124 |
| | | Female | 20,326.6 | 945.4 | 50 |
| | | Both | 24,765.9 | 1,151.9 | 174 |
| II | Middle Catchment | Male | 16,578.5 | 771.1 | 96 |
| | | Female | 10,262.9 | 477.3 | 38 |
| | | Both | 14,787.7 | 687.8 | 134 |
| III | Upper Catchment | Male | 17,364.8 | 807.7 | 109 |
| | | Female | 12,234.0 | 569.0 | 48 |
| | | Both | 15,796.1 | 734.7 | 157 |
| IV | Overall HRC | Male | 20,595 | 957.9 | 329 |
| | | Female | 14,669 | 682.3 | 136 |
| | | Overall | 18,862 | 877.3 | 465 |

**Source:** Own Computation via SPSS (2018) upon Own Survey Data (2016 – 2017)

Result of the study revealed that, difference in average income of HH from crop and fuel-wood products was statistically significant at 95% upon difference in gender, family (HH) size and "farm-size" among HH in each of the Sub-catchments (that is LC, MC and UC) (Table 7.1 above; Table 7.1a, Appendix IV). Gender difference-based variation of average income derived from crop and fuel-wood products by HH

of the LC (with F statistic of4.506 and sig value of 0.035), MC (with F value of 17.931 and sig value of 0.000) and UC (with F value of 7.317 and sig value of 0.008) was statistically significant at 95% level of confidence (Table 7.1a, Appendix IV); that is, average income generated from the products by female-headed HH of the LC (US$ 945.4), MC (US$ 477.3) and UC (US$ 569) was significantly smaller than that of male-headed HH of the respective Sub-catchments (that is, US$ 1,235.2, US$ 771.1 and US$ 807.7, respectively) (Table 7.1 above). Similarly, significant variation in average income from crop and fuel-wood services was also observed among HH of the LC, MC and UC upon difference in family (HH) size at 95% confidence interval; that is, where the F statistics and significance values (in brackets) of the respective Sub-catchments were 55.737 (0.000), 7.58 (0.000) and 17.124 (0.000) (Table 7.1a, Appendix IV). In other words, the estimated average gross income from crop and fuel-wood products was significantly larger for HH with more or larger "family size" than that of those HH having smaller family size in each of the Sub-catchments (that is LC, MC and UC). Moreover, assuming "landholding size" as a major source of income for the rural inhabitants of the LC, MC and the UC, one-way ANOVA was conducted about average income generated from crop harvest and fuel-wood (firewood and charcoal) products by HH of each Sub-catchment based on "farm-size" as a criteria of comparison of earning variation among residents; and, result of the analysis showed that variation of average income from these provisioning products (between households) was statistically significant in the LC, MC and UC at 95% confidence interval upon difference in "farm-size" (ha/HH); that is, where the F statistics and significance values (in brackets) of the LC, the MC and the UC were 51.369 (0.000), 17.94 (0.000) and 54.403 (0.000), respectively (Table 7.1a, Appendix IV). The implication is that, the estimated average income was larger for most HH with larger "farm-size" and it was smaller for most of those who held smaller "farm-size" in each of the three Sub-catchments (LC, MC and UC).

The estimated average gross income (US$/HH/Year), from crop and fuel-wood (firewood and charcoal) products, was the largest for HH of the LC (that is US$ 1,151.9), and it was the smallest for HH of the MC (US$ 687.8) in 2015/16. The average earning from the products was estimated at US$ 734.7/HH/year for residents of the UC. The per capita gross income from crop and fuel-wood products of the LC, MC and UC was estimated at US$ 230.4, US$ 137.6 and US$ 146.9 per/person/year in 2015/16, respectively (Table 7.2 below). Evaluating the NEV of nature through the two sets (crop and fuel-wood) of products requires considering (deducting) the cost of generating the products from existing ecological systems of HRC (Freeman, 2003). In this regard, average NEV of nature (in US$/HH/year) through crop production and fuel-wood products was the largest (US$ 1,073.6) in LC, moderate (US$ 674.8) in the UC and the

smallest (US$ 633.5) in the MC in 2015/16; and, the per capita NEV of nature through these products was estimated at US$ 214.7, US$ 126.7 and US$ 134.9 per/person/year for inhabitants of the LC, the MC and the UC, respectively (Table 7.2).

## 7.2 Distribution of Income (from the Products) among HH of the Whole HRC

Under this sub-heading, the emphasis is about the estimated gross income and NEV of nature through crop and fuel-wood products (generated) by HH of the whole HRC. As it is illustrated in Figure 7.1b below, the estimated gross income generated from crop and fuel-wood products by greater proportion (38.3%) of the HH of HRC was ETB 10,001 – 20,000 (US$ 465.15 – 930.20) annually (in 2015/16).

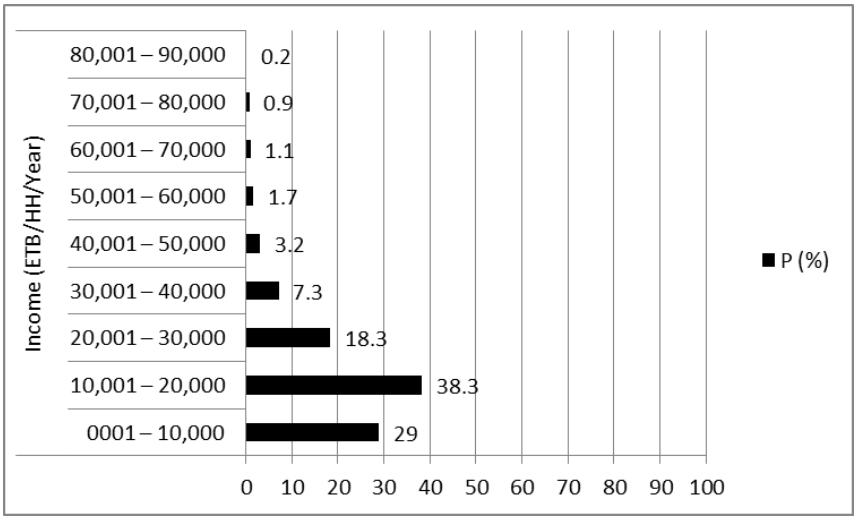


Figure 7.1b Distribution (%) of HH of the Whole HRC upon Level of Estimated Income from Crop Harvest and Fuel-Wood (FW and Charcoal) Services in 2015/16

The gross earning did not exceed ETB 10,000 (US$ 465.10) for slightly less than one-third (29%) of the HH annually; of the 29% HH of HRC (with earning US$ 465.1 and smaller), about 13.1%, 9.5% and 6.4% of them were from the UC, MC and the LC, respectively. Anyway, the estimated income from both sets (crop and fuel-wood) of products did not exceed about ETB 20,000 (US$ 930.20) for about two-third (67.3%) of the HH of the Catchment (see Figure 7.1b). The gross income from the services was estimated at ETB 30,0001 – 90,000 (US$1,395.35 – 4,185.90) for only 14.4% of the HH of HRC in the period accounted by the study. Households of HRC who earned ETB 50,001 – 90,000 (US$ 2,325.55 - 4,185.90) constituted only 3.9%, all of whom were from the LC (see Figure 7.1a and Figure 7.1b above).

Gender difference-based variation of average gross income from crop plus fuel-wood (firewood and charcoal) products was statistically significant among HH of HRC at 99% confidence interval; that is,

where the F statistic was 17.098 and its significance value was 0.000 (Table 7.1b, Appendix IV). Meaning, the estimated average income derived from crop and fuel-wood products by male-headed HH (US$ 957.9) of the Catchment significantly exceeds that of the female-headed (US$ 682.3) counterparts in the whole HRC (see Table 7.1 above). Variation of average gross income from crop and fuel-wood products was also significant at 99% confidence interval based on difference in "family (HH) size" among HH of HRC; that is, where the F statistic was 22.817 and its significance value was 0.000 (Table 7.1b, Appendix IV). The implication is that, the estimated average revenue/income derived from the two sets (crop and fuel-wood) of products was significantly larger for HH of HRC with larger HH-size, and smaller for those having smaller family size. One-way ANOVA was also run using "farm-size" as criteria (factor) of comparison of the variation in average earning from crop and fuel-wood products among HH of HRC, assuming that "farm-size" is a major source of income for inhabitants of the Catchment; as a result, difference in "farm-size" among rural HH of the Catchment could influence (increase or decrease) the level of households' (fuel-wood) energy consumption in the area. Anyway, result of the ANOVA revealed that, "farm-size" difference-based variation of estimated average income from the products was statistically significant among HH of HRC at 99% level of confidence; that is, where the F statistic was 98.922 and the significance value was 0.000 (Table 7.1b, Appendix IV). This implies that most HH of HRC who have (or held) larger "farm-size" generated significantly larger average income from crop and fuel-wood products than those HH with smaller farm-size.

Results of the study about average and per capita gross income and NEV from crop and fuel-wood (firewood and charcoal) products were measurement and summarized both at Sub-catchment (that is LC, MC and UC) and overall HRC levels (Table 7.2). The estimated average gross income from these products of the whole HRC was about US$ 877.3 per/HH/year in 2015/16. The per capita gross income from the products in the whole study area was US$ 175.5 per/person/year (Table 7.2). "Independent sample t-test" was used to prove whether or not the difference in average income from crop and fuel-wood products between HH of the three Sub-catchments (that is the LC, MC and UC) is statistically significant.

Table 7.2: Average Gross Income (GI), Net Economic Value (NEV), Per Capita GI and Per Capita NEV Derived from Crop and Fuel-wood (Firewood and Charcoal) Products by HH of HRC in 2015/16

| N0 | Service | N0 | Measurement | LC | MC | UC | HRC |
|---|---|---|---|---|---|---|---|
| I | Crop harvest | 1 | Average gross income (US$) | 971.4 | 499.3 | 556.5 | 695.3 |
| | | 2 | Average NEV (US$) | 893.1 | 445.0 | 496.6 | 630.1 |
| | | 3 | Per capita gross income (US$) | 194.3 | 99.9 | 111.3 | 139.1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 | Per capita NEV(US$) | 178.6 | 89.0 | 99.3 | 126.0 |
| II | Fuel-wood | 5 | Average gross income (US$) | 180.5 | 188.5 | 178.2 | 182.0 |
| | | 6 | Average NEV (US$) | 180.5 | 188.5 | 178.2 | 182.0 |
| | | 7 | Per capita gross income (US$) | 36.1 | 37.7 | 35.6 | 36.4 |
| | | 8 | Per capita NEV (US$) | 36.1 | 37.7 | 35.6 | 36.4 |
| III | Crop and fuel-wood services | 9 | Average gross income (US$) | 1,151.9 | 687.8 | 734.7 | 877.3 |
| | | 10 | Average NEV (US$) | 1,073.6 | 633.5 | 674.8 | 812.1 |
| | | 11 | Per capita gross income (US$) | 230.4 | 137.6 | 146.9 | 175.5 |
| | | 12 | Per capita NEV (US$) | 214.7 | 126.7 | 134.9 | 162.4 |
| | | 13 | HH size | 5 (5.4) | 5 (5.2) | 5 (5.1) | 5 (5.3) |
| | | 14 | Sample HH | 174 | 134 | 157 | 465 |

Source: Own Computation (2018) upon Own Survey Data (2016 – 2017)

The result revealed that, variation of estimated average income from the products between HH of the LC and MC (with t-statistic of 6.39 and significance value of 0.000), and the LC and UC (with t-statistic of 5.79 and significance value of 0.000) was significant at 99% confidence interval; in other words, the estimated average income generated, from crop harvest and fuel-wood products, by HH of the LC (US$ 1,151.9) was significantly larger than that of the MC (US$ 687.8) and the UC (US$ 734.7) (Table 7.2 above). However, though there was a difference in average income (US$/HH/year) from crop and fuel-wood products between HH of the MC (US$ 687.8) and the UC (US$ 734.7), the variation was not statistically significant both at 99% and 95% level of confidence (that is, where the t-statistic was -0.93 and its significance value was 0.354) (Table 7.1c, Appendix IV). Net economic value (NEV) of nature from crop and fuel-wood products was estimated at US$ 812.1/HH/year in overall HRC. Upon this figure (US$ 812.1), the per-capita NEV of these products of nature for residents of the whole study area became US$ 162.4/person/year (Table 7.2 above).

Valuation of cropland services of HRC, in this study, was carried out on total harvest of crops (by smallholder farmers) in 2015/16 production season; that is, valuation or measurement was made on output of crops, which is meant for both market (cash) and non-market (for home consumption) purposes. However, fuel-wood (firewood and charcoal) products measured, here, were the services, which had been used (by rural HH of HRC) only for home energy consumption; in other words, the study did not account fuel-wood products (especially charcoal) exploited largely by the poor for generating income for livelihood needs. This is because, sample HH declined to provide genuine evidences about charcoal production for cash as they know that exploiting this fuel-product from common pool resources is restricted by law. Generally, the estimated average gross income (US$ 877.3/HH/year) from crop harvest and fuel-wood (firewood and charcoal) products of the whole HRC was significantly smaller than the

corresponding estimated figure (US$ 1,322/HH/year) of Bale Mountain Ecosystem in Southeastern Ethiopia (Watson, 2007).

# Chapter Eight

# Conclusion and Recommendation

## 8.1 Conclusion

Based on findings of the study about magnitudes, trends and impacts of ESV dynamics, and current values of crop and fuel-wood products of HRC, the following conclusive remarks were pinpointed.

HRC experienced LULC dynamics-led net ESV loss and decreasing trend of ESV in periods 1967 –2015. Net ESV loss of HRC is over half of the total service value of the area during the base year (1967). The largest share of the ESV loss had emanated from the depletion of key services given by forest, riverine vegetation and woodland such as food and raw materials, air and climate regulation, nutrient cycling, erosion control, waste treatment, and other services. Dwindling carbon sink and air regulation services of forest and woodland-induced rising temperature, and rising evaporation or temperature-led increment of rainfall are among the adverse effects of ESV loss in HRC. Hare River also revealed declining annual discharge, which was a direct impact of increasing siltation in lower course of the river and rising evaporation in the Catchment; in other words, decreasing water flow of Hare River is indirectly a consequence of ESV loss such as, decreasing carbon storage and erosion control services of forest, woodland, riverine vegetation, bush and grassland covers in the area.

ES dynamics of HRC is triggered by *negative*, *positive* and *neutral drivers* of change. Growing population-led clearing of land covers for crop farming and settlement, extraction of fuel-wood and timber, over-browsing and overgrazing are the main *negative drivers* of the ESV loss from forest, riverine vegetation, bush/shrub, woodland and grassland in HRC. Whereas, actions such as afforestation, control of illegal tree-cutting, agro-forestry practices of farmers and area-closure are *positive drivers* of ESV changes. LULC change is the main *neutral driver* of ESV loss in HRC.

Residents of HRC gain relatively low annual average harvest, gross income and NEV from croplands. HH of the LC derive significantly larger average harvest, gross income and NEV from croplands than that of the MC and UC counterparts. Average production and income from croplands reveal significant variations among HH of the LC, MC, UC and overall HRC based on difference in ‘gender,’ ‘HH size,’ ‘farm size,’ ‘labor’ and ‘fertilizer’ used for cultivation; that is, average yield and income from crop

harvest is significantly lower for female-headed HH (except in LC), farmers having smaller average 'family' and 'farm' size, and those who use lower average 'labor' and 'fertilizer' for cultivation. But, gender-difference based variation of average yield and income is not significant in the LC. Crop farming in the LC of Hare is threatened by moisture scarcity and perishable nature of fruits due to the hot climate; whereas, production in the MC and UC is affected by smaller farm-size, cultivation on steep slopes, severe runoff erosion, shallow, less fertile and acidic soils, inadequate and inappropriate conservation practices, and exploitation of land for the same crops for centuries. Exchanging fruit products at lower prices (due to spoilage problem) and lack of preserving technology for the fruits are also other challenges on income from crop harvest by HH of HRC, Southern Ethiopia.

Farm inputs such as 'farm size,' 'labor,' 'fertilizer,' 'seedlings' and 'seeds' used for farming are significant predictors of crop 'harvest' variation among HH of HRC at 99% CI; and, these variables are also significant predictors of yield in the LC (except "seed"), MC and UC. The influence of "seed" and 'oxen-power' use variation on crop 'harvest' is not significant in the LC; this is because, use of seeds and oxen power (per/HH/year) in the area is limited as the crops (like banana, mango, avocado, papaya, etc.,) which contribute the lion share of the total annual "harvest" are perennials - requiring limited oxen power-based land management every production season and which need 'seedlings' as direct input instead of seeds. Farm-size is the strongest significant predictor of crop 'harvest' variation among HH of the LC and overall HRC (at 99%) as farmland in the LC is largely plain and fertile. But, labor is the strongest significant predictor of production variation among HH of the MC and UC. Labor in the MC and UC is uniquely used for tillage using a tool, known as, *tsoile* (a traditional hoe), that is, largely without the aid of oxen-power where most crops grown are annuals requiring land preparation every growing season. Thus, crop farming in these Sub-catchments is largely labor-intensive.

Average consumption of and income from fuel-wood (firewood and charcoal) products for HH of the LC, MC, UC and HRC is low. 'Gender,' 'family size' and 'location' difference-based variation of average consumption of and earning from firewood among HH was significant at 95% CI; meaning, average firewood consumption and value of female-headed HH is significantly smaller than that of the male-counterparts. Similarly, consumption and value of firewood for HH having smaller family size is significantly lower than those with larger family size. Average consumption of and income from firewood between HH of the LC and MC, and the MC and UC is significant at 95% CI; that is, average firewood consumption and value for HH of the MC was significantly larger than that of the LC and the UC due to

better access to forest, woodland and bush. Variation in average value (US$) of fuel-wood (firewood and charcoal) consumption among HH of HRC is significant at 95% CI based on difference in gender, family size and income status; that is, value (US$) of the fuel-services for female-headed HH is significantly smaller than that of the male-headed ones, and it is also significantly smaller for HH having smaller family size and low income status than those with more family size and better income, respectively. The low average annual consumption and value (US$) of fuel products (in HRC) is a synergy of the residents' dependence on diverse energy sources [like hydro-power (in LC only), gas (gasoline), solar cell energy, animal dung and crop residue, other than firewood and charcoal], the continuous shrinkage of forest, riverine vegetation and woodland, and dwindling supply of fuel-wood products within 1967 – 2015, underlain by growing population.

Current level of gross income (US$/HH/year) and NEV (US$/HH/year) from crop harvest and fuel-wood (firewood and charcoal) products by HH of the MC, UC and overall HRC is somewhat low. 'Gender,' 'family size' and 'farm-size' difference-based variation of average income from crop and fuel-wood products is statistically significant among HH of the LC, MC and UC at 95% CI, and also in whole HRC at 99% CI; that is, income (US$/HH/year) of female-headed HH, and HH having smaller 'family size' and 'farm-size' is significantly smaller than that of male-headed ones, and those HH with larger family and farm size, respectively. There is also a significant variation in average income among HH of HRC at 99% CI upon difference in Sub-catchment, that is, between the LC versus the MC, and the LC versus the UC. Meaning, income (US$/HH/year) from crop and fuel-wood products of the LC is significantly larger than that of the MC and UC. The significant earning difference (between these Sub-catchments) originates largely from the highly fertile soils, better farm-size and larger land productivity of the LC (that is, contrary to the MC and UC).But, variation of income (US$/HH/year) from crop and fuel-wood products between HH of the MC versus the UC is not significant at 95%.

Generally, the high level of overall ESV loss overtime (1967 – 2015) and the low level of current (2015/16) values of crop and fuel-wood products reveal that depletion of environmental resources has long been a persistent problem of HRC in four to five decades. That is, exploitation of ecological services has not been on sustainable basis, the interventions for rehabilitation of degraded resources were inadequate, and even in some cases, the measures were less effective.

## 7.2 Recommendation

**Part I: Management Options about Problems of overall Ecological (and Fuel-wood)Services**

Ethiopian government should direct its policy towards resilience of resources on degraded ridges/hills and uncultivated lands of HRC, which were once covered with forest, woodland, etc., perhaps, via payments for ecosystem services; that is, by integrating the options pointed out below.

First, structural (such as bench terraces, check-dams/gabion, micro-basins, etc.,) and vegetative measures (afforestation, planting valuable grasses, agro-forestry, etc.,) should be intervened (upon catchment development principles) by the coordinated efforts of stakeholders (local to national) such as experts or planners(in integrated catchment development, forestry, etc.,), administrators, and inhabitants of HRC. And, these measures should be supported by "area-closure" (wherever needed) for effective rehabilitation of natural resources on degraded lands. Interventions should be taken on account of existing physical, economic and socio-cultural contexts in the area such as local knowledge, skill, experience, material supply, etc., about conservation and management of resources, livelihood means of the local people, and so on.

In connection with vegetative measures, it is advisable for individual HH of HRC to plant tree species such as eucalyptus (*eucalyptus citriodora*), olive (*cuspidate olea africana*), mexican cyprus or *yefereji-tid* (*cupressus lusitanica*), mountain bamboo (*arundinaria alpine*),reed-grass (*shembeko*), etc.,nearby homestead, in steep (pocket) areas, along banks of streams/tributaries of Hare, etc. These species of trees are useful for rehabilitation of degraded land, some of these trees would be reliable sources of fuel-wood for home use by HH of the MC and UC, and they would also be good sources of cash through supply of timber and traditionally processed household furniture, tools, etc.

The Ethiopian government and NGOs should provide renewable energy source options (like solar energy, biogas, and/or hydo-power, etc.,) for rural HH of the country, including HRC. The government and NGOs should also focus on the provision of technologies that enable efficient and conserved use of energy sources for home (cooking, heating, etc.,) purposes. These measures are thought to curtail fuel-products' exploitation-induced burden on forest, woodland, riverine vegetation, etc., resources of HRC by mitigating shortage of energy and improving efficiency of household energy consumption.

The government, investors and farmers should also focus on agro-forestry options so as to mitigate cropland expansion-driven ESV loss. Thus, farmers in the LC could focus on banana, mango, avocado, papaya, coffee, and other new fruits from areas with similar agro-ecology; whereas, apple, *enset* and other tree-crops from other areas with similar agro-climate could be used by farmers in the MC and UC. So, institutions (Agriculture Research Centers, Colleges of Agriculture, etc.) should provide expertise support for farmers in domesticating new agro-forestry/tree crops in HRC.

The Ethiopian government should also integrate objectives of ecological resilience actions with other national (and regional) development goals, such as improving income, poverty reduction, ensuring food security, employment creation, etc. These interventions are valuable for enhancing the commitment and participation of different social groups (like poor, youth, women, etc.,) of HRC in the efforts towards the sustainable restoration of ecological resources and their services.

**Part II: Management Options about Threats on Croplands and their Services**

The Ethiopian government should emphasize on "integrated" measures that could be applied upon catchment development principles so that management and yield-related threats of croplands would be surmounted. Measures to be intervened on croplands by the coordinated efforts of experts/planers (in sustainable land management, soil and water conservation, etc.), administrators, farmers, etc., should integrated: ***(i)*** *Structural*: bench terraces and stone bunds have to be practiced on steep farm-plots of the MC and UC so that level of erosion would be minimized as a result of reduced slope length and gradient, raised infiltration and suppressed runoff. ***(ii)****Biological*/*agro-forestry*: alternating legume plants and tree-crops [say apple, '*gesho'* (*rhamnus prinoides), enset*, etc., perennials] with annual crops (in rows), grass-strips with farm-plots, etc., is useful for improving soil nutrient, reducing erosion and minimizing fodder shortage. ***(iii)*** *Agronomic measures*: crop rotation, mixed-cropping, manure, compost, mulching, chemical fertilizers, etc., should be applied by farmers so as to enhance the fertility and productivity of land. Farmers of the LC should mulch farm-plots, construct water-harvest hallows, ridges/furrows and micro-basin so as to mitigate the moisture stress constraint of crop farming.

Since the lion's share of the 2015/16 total crop harvest of HRC was derived from recently introduced fruits (banana, mango and apple), farmers should domesticate new crops from areas with similar agro-climate – which needs support from different stakeholders (Agricultural Research Institutions, Agriculture Colleges, NGOs, etc.). It also requires a policy attention from the Ethiopian government.

The suggested solutions (pointed above) should be practiced through gradual and lesson acquired from "experience;" that is, the actions should not be run upon a campaign-based community mobilization like the way it has been done by the Ethiopian government since some years past. A campaign-based catchment development may not keep the standard and quality of the work; and measures practiced in the same way were rarely sustainable as it was observed from past experiences in Ethiopia. A pilot-based strategy that considers the consent of individual farmers have to be followed for the successful practice of measures; that is, the measures should be implemented in selected sites, first and scaling up the solutions should proceed upon lesson acquired from previous experiences.

The government of Ethiopia should focus on "import-substitution policy" through investment in small scale fruit-processing factory nearby or within Arba Minch town upon further study about the matter. This measure is useful to reduce the foreign currency required for importing processed goods (juice, soft-drinks, etc.,) at expensive prices from countries importing fruit products (the raw materials) from Ethiopia; it is also useful for surmounting spoilage problem of fruits of HRC and minimizing exchange of the products at unfairly cheaper prices. As farmers of the MC and UC of Hare are still reliant solely on hoe (*tsoile*)-based land preparation, stakeholders (government, Agriculture Research Institutes, Technology Transfer Institutions, etc.) should work for innovation and/or provision of a better technology capable of improving the efficiency of labor in land preparation in the area.

Finally, the Ethiopian government should provide special policy attention and support for female-headed households so as to minimize gender-difference based variation of average crop harvest from croplands of HRC. That is, the government and NGOs should support female farm HH in training, extension services and other supports such as application of improved farm inputs (fertilizer, seeds, etc.), methods of crop cultivation, access to credit, fair/equitable landholding, and so on.

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# Appendices:

## Appendix I: Questionnaire and Interview

**Addis Ababa University**

**School of Graduate Studies**

**Department of Geography and Environmental Studies**

### Part 1: Household Survey Questionnaire for LC and Overall HRC:

**Dear respondent:**

The main objective of this questionnaire is to gather information useful for analyzing and addressing the challenges of environmental services dynamics, and the threats on the flow and values of cropland, forest, etc., services in HRC. Frankly speaking, the information obtained through the questionnaire survey shall be purely used for academic purpose only. Moreover, I confirm you that the information obtained from you would be kept confidential. Therefore, I kindly request you a genuine cooperation in providing appropriate responses for the questions incorporated in this questionnaire.

Thank you in advance!!

**Preliminary Information:**

i. Name of enumerator_____ iv. Location/sub-catchment _____

ii. Date of enumeration _____ v. Name of KPA _____

iii. Interviewee's code (N0) _____ vi. *Woreda* _____

**I. Personal Information of Respondents [put a tick mark (√) in the box in front of your choice]:**

1) Sex of the respondent: 1. Male ☐ 2. Female ☐

2) Age of the respondent: 1. 15 – 24 ☐ 2. 25 – 34 ☐ 3. 35 – 44 ☐

4. 45 – 54 ☐ 5. 55 – 64 ☐ 6. > 64 ☐

3) Marital status: 1. Single ☐ 2. Married ☐

3. Divorced ☐ 4. Widowed ☐

4) Educational status: 1. Illiterate ☐ 2. Read & write only ☐ 3. Elementary: ☐ 4. Junior ☐

5. Secondary school ☐ 6. Certificate ☐ 7. Diploma & above ☐

5) Household size: 1. 1 - 3 ☐ 2. 4 - 6 ☐ 3. 7 – 9 ☐

4. 10 – 12 ☐ 5.13 – 15 ☐ 6. 16 – 18 ☐

6) Household head: 1. Male ☐ 2. Female ☐

7) Number of years you have lived in your current residence: 1. 1 – 6 ☐ 2. 7 – 12 ☐

3. 13 – 18 ☐ 4. 19 – 24 ☐ 5. 25 – 30 ☐ 6.> 30 ☐

8) Farm size of the household (in hectare)? _____hectare

## II. Information on Selected Current Environmental Services and Change Drivers of Services:

### A) Cropland services [Put a tick mark (√) in the box in front of your choice]:

1) What is your main occupation? (Multiple responses possible):

1. Crop cultivation ☐ 2. Livestock raising ☐ 3. Retailing (trade) ☐

4. Employee (gov't or private) ☐ 5. Other: _____

2) If you practice "crop cultivation," to what extent is your farm size?

1. 0.01 – 0.25 ha: ☐ 4. 0.76 – 1.00 ha ☐ 7. 1.51 – 1.75 ha ☐ 9. 2.26 – 2.50 ha ☐

2. 0.26 – 0.50 ha ☐ 5. 1.01 – 1.25 ha ☐ 8. 1.76 – 2.00 ha ☐ 10. 2.51 – 2.75 ☐

3. 0.51 – 0.75 ha ☐ 6. 1.26 – 1.50 ha ☐ 9. 2.01 – 2.25 ha ☐ 11. > 2.75 ha ☐

3) If you produce crops, which category of crops do you cultivate? (Multiple responses possible):

1. Fruits crops ☐ 3. Tuber & root crops ☐ 5. Vegetables ☐

2. Cereal crops ☐ 4. Pulses ☐ 6. Other: _____

4) If you cultivate fruits, which of the following ones do you cultivate? (Multiple responses possible):

1. Banana ☐ 4. Tomato: ☐ 7. Pepper ☐

2. Mango ☐ 5. Apple: ☐ 8. Other: _____

3. Avocado ☐ 6. Papaya ☐

5) If you produce "banana" and/or "mango," how much is the land covered by these two fruit crops? ____ ha:

6) If you grow banana, when do you harvest the production of the fruit? (Multiple responses possible):

1. September to November ☐ 3. March to May ☐ 5) Throughout the year ☐

2. December to February ☐ 4. June to August ☐ 6) Other: _____

7) If you cultivate banana, how many quintals of banana do you harvest per year? _____ Quintal

8) If you grow mango, when do you harvest the fruit? (Multiple responses possible):

1. September to November ☐ 3. March to May ☐ 5) Throughout the year ☐

2. December to February ☐ 4. June to August ☐ 6) Other: _____

9) If you cultivate mango, how many quintals of mango do you harvest per year? _____ Quintal

10) How many quintals of production, on average, do you get from each of the fruit crops cultivated on your farmland annually (say this year)? Put a tick-mark (√) to indicate your response: **Note**: **in the Table above**, list

out names of fruits in rows 7 & 8 if you are cultivating additional ones other than those mentioned in numbers 1 - 6, and put the amount of yield of each per year;

**Table 1: Use the following table to indicate amount of yield of fruits annually:**

| N0 | Fruits | Amount of Production per/Year (in Quintals) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1-10 | 11-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | 81-90 | 91-100 | >100 |
| 1 | Banana | 1-10 | 11-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | 81-90 | 91-100 | >100 |
| 2 | Mango | 1-10 | 11-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | 81-90 | 91-100 | >100 |
| 3 | Tomato | 1- 3 | 4 - 6 | 7 - 9 | 10 –12 | 13 -15 | 16 -18 | 19 –21 | 22 –24 | 25-27 | 28-30 | >30 |
| 4 | Avocado | 0.1-1 | 1.1-2 | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1-10 | >10 |
| 5 | Papaya | 0.1- 1 | 1.1 - 2 | 2.1 - 3 | 3.1 – 4 | 4.1 - 5 | 5.1 - 6 | 6.1 – 7 | 7.1 – 8 | 8.1-9 | 9.1-10 | >10 |
| 6 | Lemon | 0.1- 1 | 1.1 - 2 | 2.1 - 3 | 3.1 – 4 | 4.1 - 5 | 5.1 - 6 | 6.1 – 7 | 7.1 – 8 | 8.1-9 | 9.1-10 | >10 |
| 7 | *Gishita* | 1- 3 | 4 - 6 | 7 - 9 | 10 –12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |
| 8 | | 1- 3 | 4 - 6 | 7 - 9 | 10 –12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |

11) If you cultivate cereals, which of the cereal crops do you produce? (Multiple responses possible):

1. Maize ☐ 3. Barely ☐ 5) *Teff* ☐
2. Sorghum ☐ 4. Wheat ☐ 6) Others: _____

12) If you cultivate pulses, which of the pulses do you produce? (Multiple responses possible):

1. Bean ☐ 2. Pea: ☐ 3. Haricot bean ☐ 4. Others: _____

13) How many quintals of yield, on average, do you get from each of the cereal crops and pulses cultivated on your farmland annually (say this year)? Put a tick-mark (√) to indicate your response:

**Table 2: Use the following table to indicate amount of yield of cereals & pulses annually:**

| N0 | Crops | Amount of Production per/Year (in Quintals) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Maize | 1- 3 | 4 - 6 | 7 - 9 | 10 – 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |
| 2 | Sorghum | 1- 3 | 4 - 6 | 7 - 9 | 10 – 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |
| 3 | Barely | 1- 3 | 4 - 6 | 7 - 9 | 10 – 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |
| 4 | Wheat | 1- 3 | 4 - 6 | 7 - 9 | 10 – 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |
| 5 | H. bean | 0.1-1 | 1.1-2 | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1-10 | >10 |
| 6 | *Teff* | 0.1-1 | 1.1-2 | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1-10 | >10 |
| 7 | Millet | 1- 3 | 4 - 6 | 7 - 9 | 10 – 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |
| 8 | Corn | 1- 3 | 4 - 6 | 7 - 9 | 10 – 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |

14) If you grow tuber & root crops which type of this category do you produce? (Multiple responses possible):

1. Potato ☐ 3. Sweet potato ☐ 5) Onion ☐
2. Cassava ☐ 4. *Boyna &/Godere* ☐ 6) Others: _____

15) What amount of yield, on average, do you get from the tuber & root crops, and pepper cultivated on your farmland annually (say this year)? Put a tick-mark (√) to indicate your response:

**Table 3: Use the following table to indicate amount of yield of tuber &root crops annually:**

| N0 | Crops | Amount of Production per/Year (in Quintals) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Potato | 1- 3 | 4 – 6 | 7 - 9 | 10 - 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |
| 2 | Cassava | 0.1-1 | 1.1-2 | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1-10 | >10 |
| 3 | S. potato | 0.1-1 | 1.1-2 | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1-10 | >10 |
| 4 | *Boyna* | 0.1-1 | 1.1-2 | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1-10 | >10 |
| 5 | *Godere* | 0.1-1 | 1.1-2 | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1-10 | >10 |
| 6 | Onion | 1- 3 | 4 – 6 | 7 - 9 | 10 - 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |
| 7 | Pepper | 0.1-1 | 1.1-2 | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1-10 | >10 |
| 8 | | 1- 3 | 4 – 6 | 7 - 9 | 10 - 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |

16) If you cultivate vegetables, list out the vegetables produced by your family? (Multiple responses possible):

1. Cabbage ☐ 3. Salad: ☐ 5. Others: _____
2. Lettuce ☐ 4. Spinach ☐

17) Do you or your family cultivate *enset*? 1. Yes ☐ 2. No ☐

18) If your response to Q.N0 17 is "Yes," how much is the estimated amount of edible enset produced by you or your family annually? _____ quintal/kg/LUM (Local Unit of Measurement);

19) Do you or your family cultivate cotton? 1. Yes ☐ 2. No ☐

20) How many quintal/kg of cotton do you or your family produces per/year? _____ quintal (kg):

21) How much is the market price per unit produce of the crops listed in the table blow this year?

**Table 4: Specify the market price of fruits, cereals & pules at local markets:**

| N0 | Crops Type | Market Price Per Unit of Produce | | | |
|---|---|---|---|---|---|
| | | Price/Kg | Price/Quintal | Price/Local Unit of measurement | Remarks |
| 1 | Banana | | | | |
| 2 | Mango | | | | |
| 3 | Tomato | | | | |
| 4 | Avocado | | | | |
| 5 | Papaya | | | | |
| 6 | Maize | | | | |
| 7 | Pepper (pimento) | | | | |
| 8 | Sorghum | | | | |
| 9 | Haricot bean | | | | |
| 10 | Teff | | | | |
| 11 | Cotton | | | | |

22) How much is the market price per/unit produce of tuber & root crops, and *enset* this year listed in Table 5?

**Table 5: Specify the market price of "tuber & root crops" and also *enset* at local markets:**

| N0 | Crop Type | Market Price Per Unit of Produce | | | |
|---|---|---|---|---|---|
| | | Price/Kg | Price/Quintal | Price per/Local Unit of Measurement | Remarks |
| 1 | Potato | | | | |
| 2 | Cassava | | | | |
| 3 | Sweet potato | | | | |
| 4 | *Boyna* | | | | |
| 5 | *Godere* | | | | |
| 6 | Onion | | | | |
| 7 | Cabbage | | | | |
| 8 | Carrot | | | | |
| 9 | *Key-sir* | | | | |

23) If you are famer, what implement do you use to prepare (plow) your farmland? (Multiple response possible):

1. Traditional hoe; ☐ 3. Tractor ☐
2. Oxen-driven implement; ☐ 4. Other: _____

24) From Q. N0 23, if you use oxen for plowing, what kind of oxen do you use? (Multiple response possible):

1. Own oxen ☐ 2. Rented oxen: ☐ 3. Oxen acquired via cooperation ☐
4. Other: _____

25) If you practice crop farming, what is/are the source/s of labor required for all farming activities (ranging from plot preparation to harvesting) in your family? Multiple responses possible:

1. Household members; ☐ 3. Cooperation from relatives & neighbors ☐
2. Wage (daily) laborer; ☐ 4. Other: _____

26) If you use HH members and/or daily laborers, how much human power (labor) have you used to carry out all farming activities for the production of this year: _____

27) If you cultivate crops, which farm inputs (other than those indicated in Q. N0 23 – 25) do you apply for the production of the crops? Multiple responses possible:

1. Fertilizer ☐ 3. Herbicide: ☐ 5. Water pumping motor ☐
2. Seeds (improved) ☐ 4. Pesticides: ☐ 6. Others: _____

28) From Q. N0 23 – 27 above, if you use farm inputs that incur cost, indicate the amount of farm input used by your family annually (say this year), and specify the cost per unit farm input in Table 6a and Table 6b below:

**Table 6a: The type and amount of labor & farm implements used by a household per year (say this year), and cost per unit of input (note: no need of specifying cost for household labor)**

| N0 | Input Type | Amount (in #) | N0 of Days the Input was Used | Cost (Birr/Input/Day) |
|---|---|---|---|---|
| 1 | Wage (daily) laborer | | | |
| 2 | Employed labor | | | |
| 3 | Water pump (rented) | | | |
| 4 | HH labor | | | |
| 5 | Pair of oxen rented | | | |

29) If your family uses oxen-power, how much is the estimated total pair of oxen power used for land preparation (that is, for production of this year)? _____ pairs of oxen-power annually;

**Table 6b: Type and amount of farm inputs used per year (say this year), and cost per unit of input**

| N0 | Input Type | Sub-type | Amount (in kg, liter or pair) | Cost (Birr/kg or Birr/liter) |
|---|---|---|---|---|
| 1 | Fertilizer | DAP | | |
| | | Urea | | |
| 2 | Herbicide | | | |
| 3 | Pesticide | | | |
| 4 | Pairs of oxen | | | - |
| 5 | | | | |

30) If you use unpurchased and purchased seedlings and seeds for crop production of this year, indicate name & amount (#/kg), and cost of purchased seedling and seed used by your family (in Table 7a & Table 7b below):

**Table 7a: Unpurchased Seedlings, Purchased Seedlings & Its Cost, and Total Seedling of Fruits Planted this Year:**

| N0 | Seedling | Unpurchased Seedling (#) | Purchased Seedlings | | Sum of Seedlings (#) |
|---|---|---|---|---|---|
| | | | Number | Cost (Birr/Seedling) | |
| 1 | Banana | | | | |
| 2 | Mango | | | | |
| 3 | Tomato | | | | |
| 4 | Avocado | | | | |
| 5 | Papaya | | | | |
| 6 | Coffee | | | | |
| 7 | | | | | |

**Table 7b: Amount of Unpurchased Seeds, Purchased Seeds & Its Cost, and Total Seed Amount of Cereals, Pulses, and Tuber & Root Crops Used for Production/Harvest of this Year:**

| N0 | Name | Unpurchased Seeds (kg) | Purchased Seeds | | Sum of Seeds (kg) |
|---|---|---|---|---|---|
| | | | Amount (kg) | Cost of (Birr/kg) | |
| 1 | Maize | | | | |
| 2 | Sorghum | | | | |
| 3 | Sweet pot | | | | |
| 4 | Haricot B | | | | |
| 5 | Cotton | | | | |
| 6 | Teff | | | | |
| 7 | Onion | | | | |
| 8 | Tomato | | | | |
| 9 | Potato | | | | |
| 10 | Millet | | | | |
| 11 | Coffee | | | | |
| 12 | Corn | | | | |
| 13 | Pepper | | | | |
| 14 | | | | | |

31) When you want to sell a crop product, how do you get it to a market? (Multiple responses possible); using:

1. Human shoulder ☐ 3) Cart & wagon ☐ 5) Other: _____

2. Pack animals ☐ 4) Vehicles ☐

**B) Forest & Woodland Products: [Put a tick-mark (√) within the box in front of your choice]**

1) Is there any forest (woodland) resource in the locality (Kebele) where you are living?

1. Yes ☐ 2. No ☐

2) If your response to Q # 1 is "yes," what kind of forest & woodland is available in your KPA?

1. Natural ☐ 2. Natural & man-made ☐ 3. Man-made ☐

3) What kind of fuel source do you use for home consumption (that is for cooking, lighting, etc.)?

(Multiple responses possible):

1. Fire-wood ☐ 3. Natural gas ☐ 5. Crop residue ☐
2. Charcoal ☐ 4. Animal dung ☐ 6. Electric power ☐
7. Others: _____

4) If you (your family) use "fire-wood" for home consumption, how do you get this energy source?

(Multiple responses possible):

1. From locally available natural woodland ☐ 2. From own planted trees ☐
3. From forest planted by the community ☐ 4. Purchased from market ☐
5. Others (if any): _____

5) If your family collects "firewood" from natural and/or man-made woodland (forest), how much time (hours) do your family members spend to collect a shoulder (tie) of firewood?

1. 0.1 – 1.0 ☐ 3. 2.1 – 3.0 ☐ 5. 4.1 – 5.0 ☐
2. 1.1 – 2.0 ☐ 4. 3.1 – 4.0 ☐ 6. 5.1 – 6.0 ☐

6) If you (your family) buy "firewood" from market, how much money do you spend for a shoulder of firewood?

1. 1 – 15 Birr ☐ 3. 31 – 45 Birr: ☐ 5. 61 – 75 Birr ☐
2. 16 – 30 Birr ☐ 4. 46 – 60 Birr : ☐ 6. 76 – 90 Birr ☐

7) If you (your family) use "firewood" as a fuel source, how many shoulders or ties of firewood do you (your family) consume per month, on average?

1. 1 – 2 ties ☐ 3. 5 – 6 ties ☐ 5. 9 – 10 ties ☐
2. 3 – 4 ties ☐ 4. 7 – 8 ties ☐ 6. 11 – 12 ties ☐

8) If you (your family) use "charcoal" for home consumption, how do you get this energy source?

(Multiple responses possible):

1. Locally available natural woodland ☐ 2. Own planted trees ☐
3. Forest planted by the community ☐ 4. Purchased from market ☐
5. Others (if any): _____

9) If you (your family) buy "charcoal" from local markets, how much money do you spend for a sack (with 50kg grain-holding capacity) of charcoal?

1. 30 – 44 Birr ☐ 3. 60 – 74 Birr : ☐ 5. 90 – 104 Birr ☐

2. 45 – 59 Birr ☐ 4. 75 – 89 Birr: ☐ 6. 105 – 119 Birr ☐

10) If you buy "charcoal" from local markets, how much money do you spend for a plastic (*kurtu*) of charcoal?

1. 1 – 3 Birr ☐ 2.4 – 6 Birr ☐ 3.7 – 9 Birr ☐ 4. 10 – 12 Birr ☐

11) If you use "charcoal" as a fuel source, how many sacks of charcoal do you consume per month?

1. 0.01 - 0.25 sack ☐ 3. 0.51 - 0.75 sack ☐ 5. 1.01 - 1.25 sacks ☐

2. 0.26 - 0.50 sack ☐ 4. 0.76 - 1.00 sack ☐ 6. 1.26 - 1.50 sacks ☐

12) Do you (your family) produce charcoal for generating income? 1. Yes ☐ 2. No ☐

13) If your response to question N0 12 above is "yes," then how many sacks (a 50kg grain size sack) of charcoal do you (your family) produce per month?

1. 1 – 5 sacks ☐ 3. 11 – 15sacks ☐ 5. 21 – 25 sacks ☐

2. 6 – 10 sacks ☐ 4. 16 – 20sacks ☐ 6. 26 – 30 sacks ☐

14) If your response to question N0 12 above is "yes," then, how much time do you or your family members spend to produce a 50kg gain size sack of charcoal?

1. 1 – 2 hours ☐ 3. 5 – 6 hours ☐ 5. 9 – 10 hours ☐

2. 3 – 4 hours ☐ 4. 7 – 8 hours ☐ 6. 11 – 12 hours ☐

15) What materials do you use for construction purposes (home, fencing, etc.)? Multiple responses possible:

1. Log/timber ☐ 3. Grass &/or crop residue ☐ 5. Soil & rock ☐

2. Bamboo ☐ 4. Cement ☐ 6. Tin & nail ☐

7. Others: _____

16) From Q. N0 15 above, if you use timber for construction, how do you get it? Multiple responses possible:

1. Harvested from the nearby natural woodland ☐ 4. Purchased from local markets ☐

2. Collected from forest planted by the community ☐ 5. Acquired from own planted trees ☐

3. Purchased from markets out of Hare Catchment ☐ 6. Others: _____

17) Is there any plant (vegetation) in your locality that is used for medical treatment of people?

1. Yes ☐ 2. No ☐

18) If your response to Q.N0 18 above is "yes," what is/are the name/s of the medicinal plant/s (in local language and/or in Amharic) in your locality? Multiple responses possible:

1. _____ 3. _____

2. _____ 4. _____

19) From Q.N0 19 above, what are the kinds of health treatments (problems) for which the medicinal plants are used in your locality? Multiple responses possible:

1. _____ 3. _____

2. _____ 4. _____

20) How much do you actually pay, on average per annum, for each of the health problems (listed in Q.N0 19 above) for which the medicinal plants are used? Use the following table to reply:

Table 8: Estimated amount spend for medicinal plants by a household annually

| N0 | Kind of Health Problem | Medicinal Plant | Average Cost (ETB/HH/Year) | Remark |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |

## C) Water Supply and Service [Put a tick-mark (√) within the box in front of your choice]

1) Is there any natural water resource (that is stream, spring, pond, etc.) in your village (Kebele)?

1. Yes ☐ 2. No ☐

2) If your response to Q. N0 1 is "yes," how do you rate the level of natural water supply in your locality/village?

1. Very abundant (excess) ☐ 3.Moderateto low in supply ☐
2. Adequate supply ☐ 4. Critically scarce in supply ☐

3) How and where do you (your family) get water used for home consumption? (Multiple responses possible):

1. Pipe water service ☐ 4. Own wheel water ☐
2. Coupon water service ☐ 5. Others (if any): _____
3. Natural sources (streams, springs, etc.) ☐

4) If you (your family) get water from natural sources (streams, springs, etc.), how much time do you (your family) spend to fatch water from these sources per day?

1. 1 – 30 minutes ☐ 3. 61 – 90 minutes ☐ 5. 121 – 150 minutes ☐
2. 31 – 60 minutes ☐ 4. 91 – 120 minutes ☐ 6. 151 – 180 minutes ☐

5) How many liters of water do you (your family) use for home consumption per day, on average?

1. 1 – 30 liters ☐ 3. 61 – 90 liters ☐ 5. 121 – 150 liters ☐ 7. 181 - 210 liters ☐
2. 31 – 60 liters ☐ 4. 91 – 120 liters ☐ 6. 151 – 180 liters ☐ 8. 211 - 240 liters ☐

6) Do you apply water for irrigation purpose? 1. Yes ☐ 2. No ☐

7) If your response to question N0 6 above is "yes," mention the kind of crops for which you apply irrigation?

1. _____ 3. _____ 5. _____
2. _____ 4. _____ 6. _____

8) If you use irrigation, what kind of physical structure do you use to store water? Multiple responses possible:

1. Traditionally constructed dam ☐ 3. Water harvesting hollow ☐
2. Modern dam ☐ 4. Others: _____

9) If you use water for irrigation, how do you apply it for cultivation? Multiple responses possible:

1. Using traditionally constructed canals ☐ 4. Through sprinkler ☐
2. Using water pumping motor ☐ 5. Others: _____
3. Through drip irrigation ☐

10) If you use "traditional dam" &/or "water harvesting hollow (hole)," then, who constructed the structures & the canals? Multiple responses possible:

1. Own power (participation) ☐ 3. Local community: ☐ 5. Others: _____
2. The government ☐ 4. NGO ☐

11) If you participate in the construction and/or maintenance of water storage structures &/or irrigation canals, how long do you or your family participate per year?

1. 1 – 5 days ☐ 3. 11 – 15 days: ☐ 5. 21 – 25 days 7. Other: ☐_____
2. 6 – 10 days ☐ 4. 16 – 20 days: ☐ 6. 26 – 30 days ☐

12) How do you express/evaluate the trend in the supply of water resource (like springs, streams, ponds, etc.) in your locality (*Kebele*) since the last twenty to thirty years?

1. Increasing ☐ 2. Decreasing ☐ 3. No change ☐ 4. It is difficult to judge ☐

**D) Drivers of LULC and ESC [Put a tick-mark (√) within the box in front of your choice]**:

1) Do you think that there have been changes in the size of forest (woodland) cover, shrub-land, grazing land, cultivated land, and other resources in your village since three – four decades?

1. Yes ☐ 2. No ☐

2) If your response to question N0 1 above is "yes," then, indicate the kind of change you have perceived (observed) on each of the land use types listed in the table below [Put a tick-mark (√) to indicate your response]:

Table 9: Observed/Perceived Changes in Land Use/Land Covers by Sample HH

| N0 | Land Use/Land Cover | Change observed/perceived | | | |
|---|---|---|---|---|---|
| | | Increased | Decreased | No change | Can't judge |
| 2.1 | Forest (woodland) cover | | | | |
| 2.2 | Grassland (grazing area) | | | | |
| 2.3 | Shrub-land cover | | | | |
| 2.4 | Cultivated land | | | | |
| 2.5 | Settlement | | | | |
| 2.6 | Water resource (springs, streams…) | | | | |

3) If your response to question N0 2.1 in Table 8 above is "decreased," what are the main causes for the decrease in woodland (forest) cover in your village? Multiple responses possible:

1. Frequent production of fire-wood & charcoal ☐ 5. Expansion of settlement ☐
2. Clearing woodland/forest for crop cultivation ☐ 6. Over browsing & overgrazing ☐
3. Exploitation of forests for construction purpose ☐ 7. Other: _____
4. Expansion of infrastructures (transport, education, health, etc.) ☐

4) Based on Q.N0 3 above, order/rank the factors from the most influential to the least one according to their contribution to the decline in woodland (forest) in your village? (Use N0 1 to 7 to rank the factors; here 1 = represent most influencing factor; and 7 = represents the least influencing factor):

Table 10: Order/rank of factors by level of contribution to the decline in woodland (forest) resource

| N0 | Factor/Cause | Rank by Level of Influence |
|---|---|---|
| 1 | Frequent production of fire-wood & charcoal | |
| 2 | Clearing woodland/forest for crop cultivation | |
| 3 | Exploitation of forests for construction purpose | |
| 4 | Expansion of infrastructures (transport, education, health, etc.) | |
| 5 | Expansion of settlement | |
| 6 | Over browsing & overgrazing | |
| 7 | Other | |

5) If your response to question N0 2.1 in Table 8 above is "increased," what are the main causes for the increase in woodland (forest) cover in your village? Multiple responses possible:

1. Individual &/or community-based tree-planting (afforestation) ☐
2. Reforestation due to the action of area closure ☐
3. Due to implementation of controlled grazing or minimization of open grazing ☐
4. Reduced fire-wood & charcoal production due to alternative energy source like biogas ☐
5. Control of illegal tree cutting through the coordinated effort of the community & the state ☐
6. Other: _____

6) If your response to question N0 2.2 in Table 8 above is "decreased," what are the main causes for the decrease in grazing land in your village? Multiple responses possible:

1. Expansion of crop cultivation ☐
2. Expansion of settlement ☐
3. Its conversion into forest cover ☐
4. Expansion of infrastructures (schools, health, road…) ☐
5. Overgrazing & erosion–induced degradation ☐
6. Others: _____

7) If your response to question N0 2.2 in Table 8 above is "increased," what are the main causes for the increase in grazing land in your village? Multiple responses possible:

1. Rehabilitation of degraded areas by area closure ☐
2. Conversion of shrub-land into grazing area ☐
3. Abandonment of cultivated fields ☐
4. Onset of controlled grazing ☐
5. Others: _____

8) If your response to question N0 2.3 in Table 8 above is "decreased," what are the main causes for the decrease in shrub-land cover in your village? Multiple responses possible:

1. Expansion of crop cultivation ☐
2. Expansion of settlement ☐
3. Its conversion into forest covers ☐
4. Infrastructure expansion (schools, health, road…) ☐
5. Over browsing & overgrazing ☐
6.Others: _____

9) If your response to question N0 2.3 in Table 8 above is "increased," what are the main causes for the increase in shrub-land cover in your village? Multiple responses possible:

1. Conversion of forest into shrub ☐ 3. Onset of controlled browsing & grazing ☐
2. Rehabilitation due to area closure ☐ 4. Others: _____

10) If your response to question N0 2.4 in Table 8 above is "increased," what are the main causes for the increase in cultivated land in your village? Multiple responses possible:

1. Conversion of grazing area into cropland ☐ 3. Change of shrub-land into cultivation ☐
2. Expansion of cultivation into forest covers ☐ 4.Others: _____

11) If your response to question N0 2.4 in Table 8 above is "decreased," what are the main causes for the decrease in cultivated land in your village? Multiple responses possible:

1. Abandonment due to sever degradation ☐ 4. Expansion of infrastructures (education,
2. Expansion of settlement ☐ health, transport, and other facilities) ☐
3. Its conversion into grazing area ☐ 5.Others: _____

12) What are the main causes for the increase in settlement in your village? Multiple responses possible:

1. Birth-induced increase in human population ☐ Rising population due to in-migration ☐
2. Expansion of institutions (education, health, religious) ☐ 4.Other: _____

13) If your response to question N0 2.6 in Table 8 above is "decreased," what are the main causes for the decrease in water resource (springs, streams, ponds) in your village? Multiple responses possible:

1. Expansion of crop cultivation ☐ 4 Variability (decline) in rainfall ☐
2. Forest degradation ☐ 5. Expansion of infrastructures (schools, health, road…) ☐
3. Rise in air temperature ☐ 6. Others: _____

14) If your response to question N0 2.6 in Table 8 above is "increased," what are the main causes for the increase in water resource in your village? Multiple responses possible:

1. Rehabilitation of degraded areas (water sources) through area closure ☐
2. Implementation of soil & water conservation practices by the community & the state ☐
3. Improvement of forest covers overtime ☐
4. Due to capacitation of surface & underground water ☐
5. Increasing rainfall amount overtime ☐ 6. Others: _____

## Part 2: Household Survey Questionnaire for the MC and UC:

**Dear respondent:**

The main objective of this questionnaire is to gather information useful for analyzing and addressing the challenges of environmental services dynamics, and the threats on the flow and values of cropland, forest, etc., services in HRC. Frankly speaking, the information obtained through the questionnaire survey shall be purely used for

academic purpose only. Moreover, I confirm you that the information obtained from you would be kept confidential. Therefore, I kindly request you a genuine cooperation in providing appropriate responses for the questions incorporated in this questionnaire.

Thank you in advance!!

**Preliminary Information:**

i. Name of enumerator_____ iv. Location/sub-catchment _____

ii. Date of enumeration _____ v. Name of KPA _____

iii. Interviewee's code (N0) _____ vi. *Woreda* _____

**I. Personal Information of Respondents [put a tick mark (√) in the box in front of your choice]:**

1) Sex of the respondent: 1. Male ☐ 2. Female ☐

2) Age of the respondent: 1. 15 – 24 ☐ 2. 25 – 34 ☐ 3. 35 – 44 ☐

4. 45 – 54 ☐ 5. 55 – 64 ☐ 6. > 64 ☐

3) Marital status: 1. Single ☐ 2. Married ☐

3. Divorced ☐ 4. Widowed ☐

4) Educational status: 1. Illiterate ☐ 2. Read & write only ☐ 3. Elementary: ☐ 4. Junior ☐

5. Secondary school ☐ 6.Certificate ☐ 7. Diploma & above ☐

5) Household size:1. 1 - 3 ☐ 2. 4 - 6 ☐ 3. 7 – 9 ☐ 4. 10 – 12 ☐

5.13 – 15 ☐ 6. 16 – 18 ☐

6) Household head: 1. Male ☐ 2. Female ☐

7) Number of years you have lived in your current residence: 1. 1 - 6 ☐ 2. 7 – 12 ☐

3. 13 – 18 ☐ 4. 19 – 24 ☐ 5. 25 – 30 ☐ 6. > 30 ☐

8) Farm size of the household (in hectare)? _____ hectare

**II. Information about Cropland services [Put a tick mark (√) in the box in front of your choice]:**

1) What is your main occupation? (Multiple responses possible):

1. Crop cultivation ☐ 2. Livestock raising ☐ 3. Retailing (trade) ☐

4. Employee (gov't or private) ☐ 5. Other: _____

2) If you practice "crop cultivation," to what extent is your farm size?

1. 0.01 – 0.25 ha: ☐ 4. 0.76 – 1.00 ha ☐ 7. 1.51 – 1.75 ha ☐ 9. 2.26 – 2.50 ha ☐

2. 0.26 – 0.50 ha ☐ 5. 1.01 – 1.25 ha ☐ 8. 1.76 – 2.00 ha ☐ 10. 2.51 – 2.75 ☐

3. 0.51 – 0.75 ha ☐ 6. 1.26 – 1.50 ha ☐ 9. 2.01 – 2.25 ha ☐ 11. > 2.75 ha ☐

3) If you produce crops, which category of crops do you cultivate? (Multiple responses possible):

1. Fruits crops ☐ 3. Tuber & root crops ☐ 5. Vegetables ☐

2. Cereal crops ☐ 4. Pulses ☐ 6. Other: _____

4) If you cultivate fruits, which of the following ones do you cultivate? (Multiple responses possible):

1. Apple: ☐ 3. Pepper: ☐ 5. Other: _____

2. Tomato ☐ 4. Cock: ☐ _____

5) If you produce "apple," how much is the size of land covered with apple? _____ hectare:

6) If you grow apple, when do you harvest the production of the fruit? (Multiple responses possible):

1. September to November ☐ 3. March to May ☐ 5) Throughout the year ☐

2. December to February ☐ 4. June to August ☐ 6) Other: _____

7) If you cultivate apple, how many quintals of apple do you harvest per year? _____ Quintal

8) If you cultivate tomato, how many quintals of tomato do you harvest per year? _____ Quintal

9) What amount of yield, on average, do you get from each of the fruit crops cultivated on your farmland annually (say this year)? Put a tick-mark (√) to indicate your response: **Note**: **in the Table below**, list out names of fruits in rows 5, 6 & 7 if you are cultivating additional ones other than those mentioned in rows 1 - 4, and show the amount of yield of each per/year;

**Table 1: Use the following table to indicate amount of production of fruits annually:**

| N0 | Fruits | Amount of yield per Year (in Quintals) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Apple | 1- 5 | 6 - 10 | 11 - 15 | 16 - 20 | 21-25 | 26 - 30 | 31–35 | 36–40 | 41-45 | 46-50 | >50 |
| 2 | Tomato | 1- 3 | 4 - 6 | 7 - 9 | 10 - 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |
| 3 | Pepper | 0.1-1 | 1.1-2 | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1-10 | >10 |
| 4 | Cock | 0.1-1 | 1.1-2 | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1-10 | >10 |
| 5 | | 1- 3 | 4 - 6 | 7 - 9 | 10 - 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |
| 6 | | 1- 3 | 4 - 6 | 7 - 9 | 10 - 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |
| 7 | | 1- 3 | 4 - 6 | 7 - 9 | 10 - 12 | 13 - 15 | 16 - 18 | 19 – 21 | 22 – 24 | 25-27 | 28-30 | >30 |

10) If you cultivate cereals, which of the cereal crops do you produce? (Multiple responses possible):

1. Barely ☐ 3. Maize ☐ 5) Others: _____

2. Wheat ☐ 4. Teff ☐ _____

11) If you cultivate pulses, which of the pulses do you produce? (Multiple responses possible):

1. Bean ☐ 2. Pea: ☐ 3. Haricot bean ☐ 4. Chick pea ☐ 5. Others: _____

12) What amount of yield, on average, do you get from each of the cereal crops and pulses cultivated on your farmland annually (say this year)? Put a tick-mark (√) to indicate your response:

**Table 2: Use the following table to indicate amount of yield of cereals & pulses annually:**

| N0 | Crop | Amount of yield per Year (in Quintals) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Barely | 1- 3 | 4 - 6 | 7 - 9 | 10 – | 13 - | 16 - | 19 – | 22 – | 25- | 28-30 | >30 |
| 2 | Wheat | 1- 3 | 4 - 6 | 7 - 9 | 10 – | 13 - | 16 - | 19 – | 22 – | 25- | 28-30 | >30 |
| 3 | Maize | 1- 3 | 4 - 6 | 7 - 9 | 10 – | 13 - | 16 - | 19 – | 22 – | 25- | 28-30 | >30 |
| 4 | Bean | 0.1- | 1.1- | 2.1- | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1- | >10 |
| 5 | Pea | 0.1- | 1.1- | 2.1- | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1- | >10 |
| 6 | Chick | 0.1- | 1.1- | 2.1- | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1- | >10 |
| 7 | | 1- 3 | 4 - 6 | 7 - 9 | 10 – | 13 - | 16 - | 19 – | 22 – | 25- | 28-30 | >30 |
| 8 | | 1- 3 | 4 - 6 | 7 - 9 | 10 – | 13 - | 16 - | 19 – | 22 – | 25- | 28-30 | >30 |

**Note**: in the Table abov**e**, list out names of cereals &/or pulses in rows 7 - 9 if you produce additional ones other than those listed in N0 1 - 6, and indicate the amount of yield of each per year;

13) If you grow tuber & root crops, which type of this category do you produce? (Multiple responses possible):

1. Potato ☐ 3. *Boyna &/godere* ☐ 5) Onion ☐
2. Cassava ☐ 4. Garlic ☐ 6) Others: _____

14) What amount of yield, on average, do you get from the tuber & root crops, and also pepper cultivated on your farmland annually (say this year)? Put a tick-mark (√) to indicate your response:

**Table 3: Use the following table to indicate amount of yield of tuber &root crops annually:**

| N0 | Crops | Amount of yield per Year (in Quintals) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Potato | 1-5 | 6-10 | 11- | 16-20 | 21-25 | 26-30 | 31–35 | 36–40 | 41- | 46-50 | >50 |
| 2 | Cassava | 0.1- | 1.1- | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1- | >10 |
| 3 | Sweet | 0.1- | 1.1- | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1- | >10 |
| 4 | *Boyna* | 0.1- | 1.1- | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1- | >10 |
| 5 | Onion | 1- 3 | 4 - 6 | 7 - 9 | 10 - | 13 - | 16 - | 19 – | 22 – | 25- | 28-30 | >30 |
| 6 | Pepper | 0.1- | 1.1- | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1- | >10 |
| 7 | Garlic | 0.1- | 1.1- | 2.1-3 | 3.1– 4 | 4.1-5 | 5.1- 6 | 6.1–7 | 7.1-8 | 8.1-9 | 9.1- | >10 |
| 8 | | 1- 3 | 4 - 6 | 7 - 9 | 10 - | 13 - | 16 - | 19 – | 22 – | 25- | 28-30 | >30 |

15) If you cultivate vegetables, list out the vegetables produced by your family? (Multiple responses possible):

1. Cabbage ☐ 3. Salad: ☐ 5. Others: _____
2. Lettuce ☐ 4. Spinach ☐

16) Do you or your family cultivate *enset*? 1. Yes ☐ 2. No ☐

17) If your response to Q.N0 16 is "Yes," how much is the estimated amount of edible *enset* produced by you or your family annually? _____ kg/quintal/LUM (Local Unit of Measurement);

18) How much is the market price per unit produce of the crops listed in the table blow, this year? You can express the price in either per/Kg, or per/Quintal, or per/Local Unit of Measurement (LUM), or in both;

**Table 4: Specify the market price of fruits, cereals & pules at local markets:**

| N0 | Crops Type | Market Price Per Unit of Produce | | | |
|---|---|---|---|---|---|
| | | Price/per Kg | Price/per Quintal | Price/per LUM | Remarks |
| 1 | Apple | | | | |
| 2 | Tomato | | | | |
| 3 | Maize | | | | |
| 4 | Pepper (pimento) | | | | |
| 5 | Barely | | | | |
| 6 | Wheat | | | | |
| 7 | Bean | | | | |
| 8 | Pea | | | | |
| 9 | Haricot bean | | | | |
| 10 | | | | | |

19) How much is the market price per unit produce of the tuber & root crops, (and also *enset*) listed in Table 5 blow this year? You can express the price in either per/Kg, or per/Quintal, or per/Local Unit of Measurement (LUM), or in both of the three (3) units of measurement;

**Table 5: Specify the market price of "tuber & root crops" and also *enset* at local markets:**

| N0 | Crop Type | Market Price Per Unit of Produce | | | |
|---|---|---|---|---|---|
| | | Price per/Kg | Price per/Quintal | Price/ Local Unit of Measurement | Remarks |
| 1 | Potato | | | | |
| 2 | Cassava | | | | |
| 3 | Sweet potato | | | | |
| 4 | *Boyna/godere* | | | | |
| 5 | Onion | | | | |
| 6 | *Enset* | | | | |
| 7 | Garlic | | | | |

20) If you are famer, what implement do you use to plow your farmland? (Multiple response possible):

1. Traditional hoe; ☐ 3. Tractor ☐
2. Oxen-driven implement; ☐ 4. Other: _____

21) From Q.N0 20, if you use oxen for farming, what kind of oxen do you use? (Multiple response possible):

1. Own oxen ☐ 2. Rented oxen: ☐ 3. Oxen acquired via cooperation ☐
4. Other: _____

22) If you practice crop farming, what is/are the source/s of labor required for all farming activities (ranging from plot preparation to harvesting) in your household? Multiple responses possible:

1. Household members; ☐ 3. Cooperation from relatives & neighbors ☐
2. Wage (daily) laborer; ☐ 4. Other: _____

23) If you use household members and/or daily laborers, how much labor force do you use to carry out all farming activities each year (say for example this year): _____

24) Which of the farm inputs (below) do you apply for production of crops? Multiple responses possible:

1. Fertilizer ☐ 3. Herbicide: ☐ 5. Water pumping motor ☐
2. Seeds (improved) ☐ 4. Pesticides: ☐ 6. Others: _____

25) From Q.N0 20 – 24 above, if you have used farm inputs that incur cost for crop harvest of this year, indicate the amount and cost per unit farm input used by your family annually, in Table 6a and Table 6b below:

**Table 6a: The type and amount of labor & farm implements used by a household per year (say this year), and cost per unit of input (note: no need of specifying cost for household labor)**

| N0 | Input Type | Amount (in | N0 of Days the Input | Cost | Remark |
|---|---|---|---|---|---|
| 1 | Wage (daily) | | | | |
| 2 | Employed labor | | | | |
| 3 | Household labor | | | | |
| 4 | Oxen rented | | | | |

26) If your family uses oxen-power, to what extent is the estimated pair of oxen power used for land preparation per/year in each production season (say for example this year)? _____

**Table 6b: Type & amount of chemical farm inputs used (this year), and cost per unit of input**

| N0 | Input Type | Sub-type | Amount (in kg or liter) | Cost (Birr/kg or Birr/liter) | Remark |
|---|---|---|---|---|---|
| 1 | Fertilizer | DAP | | | |
| | | Urea | | | |
| 2 | Herbicide | | | | |
| 3 | Pesticide | | | | |
| 4 | | | | | |

27) If you use unpurchased and purchased seedlings and seeds for crop production of this year, indicate the name and amount (in # or kg), and cost of purchased seedling (Birr/#) and seed (Birr/kg) used by your family:

**Table 7a: Amount of Unpurchased Seedling, Purchased Seedling & Its Cost, and Total Seedling of Fruit Crops Planted this Year:**

| N0 | Seedling | Unpurchased Seedling (#) | Purchased Seedlings | | Sum of Seedlings (#) |
|---|---|---|---|---|---|
| | | | Number (#) | Cost of (Birr/Seedling) | |
| 1 | Apple | | | | |
| 2 | Tomato | | | | |
| 3 | Pepper | | | | |
| 4 | Cock | | | | |
| 5 | *Enset* | | | | |

**Table 7b: Amount of Unpurchased Seed, Purchased Seed & Its Cost, and Total Seed Amount of Cereals, Pulses, and Tuber & Root Crops Used for Production of This Year:**

| N0 | Seed | Unpurchased Seeds (kg) | Purchased Seeds | | Sum of Seeds (kg) |
|---|---|---|---|---|---|
| | | | Amount (kg) | Cost (Birr/kg) | |
| 1 | Barely | | | | |
| 2 | Wheat | | | | |
| 3 | Bean | | | | |
| 4 | Pea | | | | |
| 5 | Potato | | | | |
| 6 | Onion | | | | |
| 7 | Garlic | | | | |

## Part 3: Questions Used for Interview:

1) Ecological services value of HRC revealed high magnitude of decline in response to LULC changes within 1967 – 1985. What were the main causes for this problem in the LC?
2) What was/were the causes for improvement in forest cover and for the low magnitude of ESV loss within 1985 – 1995 and 2003 – 2015?
3) Have you noticed the weather and climate changes in your locality? How do you perceive (prove) the existence of climate change (or variability) in your village?

4) How do you explain the benefits of fruit cultivation in the LC of Hare? What is/are the challenges of fruit production in the Sub-catchment?
5) How do you describe or rate the level of land productivity in the MC and UC of HRC?
6) Why production and productivity of land is low in the MC and UC of Hare? What are the main threats on land productivity for crop farming in these Sub-catchments (MC and UC)?
7) Why the use of oxen power for activities of crop farming (e.g., land preparation) is limited (or rare) in the MC and UC of HRC?
8) What improved seeds and/or seedlings were used by HH of Chano Chalba, Shama Gedie and Doko Masho KPA of HRC in 2015/16 season? How much was the price per unit input?
9) What are the major structural and biological soil and water conservation measures practiced in the LC, MC and UC of the area? What soil management (agronomic) techniques are practiced by farmers of the Catchment? What are challenges related to SWC practices in HRC?
10) What substances are used for HH energy consumption by inhabitants of HRC? How much is the price of a shoulder of firewood and a sack of charcoal in the year 2015/16?

## Appendix II: ESV Changes in Response to LULC Dynamics in HRC (Chapter 4)

**Table 4.1a: Area Change Matrices (in ha) among LULC Classes of HRC within 1967 – 1976**

| 1976<br>1967 | Forest | R. Vegetation | Crop & Settle | Bush/Shrub | Woodland | Grassland | **Total (1967)** |
|---|---|---|---|---|---|---|---|
| Forest | 136.6 | 148.0 | 1360.4 | 577.8 | 233.4 | 389.9 | **2846.1** |
| R. Vegetation | 124.2 | 185.1 | 803.7 | 765.6 | 580.6 | 70.1 | **2535.2** |
| Crop & settle | 334.0 | 384.1 | 2521.9 | 823.9 | 378.6 | 1124.6 | **5567.1** |
| Bush/shrub | 175.1 | 224.0 | 1172.8 | 1718.5 | 598.6 | 183.3 | **4072.3** |
| Woodland | 328.8 | 486.4 | 2767.4 | 1650.9 | 1157.7 | 458.9 | **6850.0** |
| Grassland | 112.5 | 107.8 | 776.3 | 195.2 | 87.5 | 282.7 | **1562.0** |

Source: Analysis via ERDAS 3.8 and Arc GIS 9.3

**Table 4.1b: Area Change Matrices (in ha) among LULC Classes of HRC within 1976 – 1985**

| 1985<br>1976 | Forest | R. Vegetation | Crop & Settle | Bush/Shrub | Woodland | Grassland | **Total (1976)** |
|---|---|---|---|---|---|---|---|
| Forest | 325.4 | 286.3 | 306.4 | 183.4 | 65.1 | 16.6 | **1183.2** |
| R. Vegetation | 173.0 | 475.1 | 551.0 | 107.8 | 138.1 | 72.8 | **1517.8** |
| Crop & settle | 75.0 | 290.8 | 7260.4 | 844.2 | 422.1 | 487.8 | **9380.3** |
| Bush/shrub | 273.6 | 209.6 | 2730.2 | 2445.0 | 139.7 | 23.3 | **5821.4** |
| Woodland | 84.8 | 282.6 | 1670.3 | 345.4 | 643.6 | 113.0 | **3139.7** |
| Grassland | 40.6 | 193.6 | 843.8 | 31.1 | 66.9 | 1214.3 | **2390.3** |

Source: Analysis via ERDAS 3.8 and Arc GIS 9.3

**Table 4.1c: Area Change Matrices (in ha) among LULC Classes of HRC within 1985 – 1995**

| 1995<br>1985 | Forest | R. Vegetation | Crop & Settle | Bush/Shrub | Woodland | Grassland |
|---|---|---|---|---|---|---|
| Forest | 423.1 | 95.5 | 51.6 | 182.4 | 107.0 | 95.5 |
| R. Vegetation | 152.9 | 722.8 | 330.1 | 125.1 | 151.2 | 255.4 |
| Crop & settle | 147.8 | 349.3 | 9767.8 | 1464.5 | 215.0 | 1491.4 |
| Bush/shrub | 189.3 | 31.5 | 879.3 | 2673.4 | 157.7 | 11.8 |
| Woodland | 111.6 | 39.1 | 581.2 | 375.4 | 324.7 | 17.4 |
| Grassland | 1.9 | 61.2 | 126.2 | 1.9 | 9.6 | 1711.6 |

Source: Analysis via ERDAS 3.8 and Arc GIS 9.3

**Table4.1d: Area Change Matrices (in ha) among LULC Classes of HRC within 1995 – 2003**

| 2003<br>1995 | Forest | R. Vegetation | Crop & Settle | Bush/Shrub | Woodland | Grassland |
|---|---|---|---|---|---|---|
| Forest | 399.5 | 104.6 | 131.8 | 119.7 | 214.3 | 36.2 |
| R. Vegetation | 212.5 | 305.9 | 221.4 | 7.7 | 325.1 | 207.4 |
| Crop & settle | 58.8 | 105.9 | 9733.1 | 647.3 | 741.5 | 482.5 |
| Bush/shrub | 101.5 | 164.3 | 1763.8 | 2019.9 | 686.2 | 96.7 |
| Woodland | 78.7 | 99.5 | 292.9 | 126.1 | 286.3 | 64.5 |
| Grassland | 32.4 | 28.8 | 1021.6 | 3.6 | 154.7 | 2356.2 |

Source: Analysis via ERDAS 3.8 and Arc GIS 9.3

**Table 4.1e: Area Change Matrices (in ha) among LULC Classes of HRC within 2003 – 2015**

| 2015 / 2003 | Forest | R. Vegetation | Crop & Settle | Bush/Shrub | Woodland | Grassland |
|---|---|---|---|---|---|---|
| Forest | 351.5 | 130.2 | 77.6 | 101.7 | 230.1 | 0.9 |
| R. Vegetation | 22.1 | 355.3 | 205.5 | 98.2 | 131..8 | 5.7 |
| Crop & settle | 26.3 | 170.8 | 11485.2 | 683.3 | 709.6 | 65.7 |
| Bush & shrub | 34.9 | 130.9 | 1233.5 | 1445.9 | 61.1 | 2.9 |
| Woodland | 158.5 | 225.8 | 595.6 | 502.0 | 910.3 | 9.6 |
| Grassland | 29.4 | 121.0 | 1193.6 | 68.7 | 598.5 | 1259.0 |

Source: Analysis via ERDAS 3.8 and Arc GIS 9.3

**Table 4.1f: Area Change Matrices (in ha) among LULC Classes of HRC within1976 - 2015**

| 2015 / 1967 | Forest | R. Vegetation | Crop & Settle | Bush/shrub | Woodland | Grassland | Total (1967) |
|---|---|---|---|---|---|---|---|
| Forest | 96.8 | 128.1 | 1758.9 | 241.9 | 404.1 | 216.3 | 2846.1 |
| R. Vegetation | 27.9 | **88.7** | 1774.6 | 438.6 | 190.2 | 12.7 | 2535.2 |
| Crop & set | 222.7 | 250.5 | **3139.8** | 233.8 | 946.4 | 773.8 | 5567.1 |
| Bush/shrub | 61.1 | 187.3 | 2716.2 | **769.7** | 272.8 | 65.2 | 4072.3 |
| Woodland | 150.7 | 404.1 | 4438.8 | 1089.1 | **623.4** | 143.9 | 6850.0 |
| Grassland | 70.3 | 56.2 | 948.1 | 31.3 | 245.2 | **210.9** | 1562.0 |

Source: Analysis via ERDAS 3.8 and Arc GIS 9.3

**Table 4.2a: ESV Gain/Loss of HRC (US$ '000') Estimated upon Change Matrices of LULC in 1967-1976**

| 1976 / 1967 | Forest | R. Veg | Crop & Settle | Bush/Shrub | Woodland | Grassland | **Total (1967)** |
|---|---|---|---|---|---|---|---|
| Forest | 0 | 0.0 | -1,193 | -426 | 0.0 | -287 | **-1,906** |
| R. Vegetation | 0.0 | 0 | -705 | -564 | 0.0 | -52 | **-1,321** |
| Crop & settle | 293 | 337 | 0 | 115 | 332 | 157 | **1,234** |
| Bush/shrub | 129 | 165 | -248 | 0 | 441 | 0.0 | **487** |
| Woodland | 0.0 | 0.0 | -2,427 | -1,217 | 0 | -338 | **-3,982** |
| Grassland | 83 | 79 | -109 | 0.0 | 65 | 0 | **118** |
| **Total (1976)** | **505** | **581** | **-4,682** | **-2,092** | **838** | **-520** | **-5,370** |

Source: Own Computation upon Costanza et al., 1997 and Yun-guo et al., 2011. **R = Riverine**

**Table 4.2b: ESV Gain/Loss of HRC (US$ '000') Estimated upon Change Matrices of LULC in 1976-1985**

| **1985 / 1976** | **Forest** | **R. Veg.** | **Crop & Settle** | **Bush/Shrub** | **Woodland** | **Grassland** | **Total** |
|---|---|---|---|---|---|---|---|
| Forest | 0 | 0.0 | -269 | -135 | 0.0 | -12 | **-416** |
| R. Vegetation | 0.0 | 0 | -483 | -79 | 00 | -54 | **-616** |
| Crop & settle | 66 | 255 | 0 | 118 | 370 | 68 | **877** |
| Bush/shrub | 202 | 154 | -382 | 0 | 103 | 0.0 | **77** |
| Woodland | 0.0 | 0.0 | -1,465 | -255 | 0 | -83 | **-1,803** |
| Grassland | 30 | 143 | -118 | 0.0 | 49 | 0 | **104** |
| Total | **298** | **552** | **-2,717** | **-351** | **522** | **-81** | **-1,777** |

Source: Own Computation upon Costanza et al., 1997 and Yun-guo et al., 2011. **R = Riverine**

**Table 4.2c: ESV Gain/Loss of HRC (US$ '000') Estimated upon Change Matrices of LULC in 1985 – 1995**

| 1995 / 1985 | Forest | R. Veg. | Crop & Settle | Bush/shrub | Woodland | Grassland | Total |
|---|---|---|---|---|---|---|---|
| Forest | 0 | 0.0 | -45 | -134 | 0.0 | -70 | **-249** |
| R. Vegetation | 0.0 | 0 | -289 | -92 | 0.0 | -188 | **-569** |
| Crop & settle | 130 | 306 | 0 | 205 | 189 | 209 | **1,039** |
| Bush/shrub | 140 | 23 | -123 | 0 | 116 | 0.0 | **156** |
| Woodland | 0.0 | 0.0 | -510 | -277 | 0 | -13 | **-800** |
| Grassland | 1 | 45 | -18 | 0.0 | 7 | 0 | **35** |
| **Total** | **271** | **374** | **-985** | **-298** | **312** | **-62** | **-388** |

Source: Own Computation upon Costanza et al., 1997 and Yun-guo et al., 2011. **R = Riverine**

**Table 4.2d: ESV Gain/Loss of HRC (US$ '000') Estimated upon Change Matrices of LULC in 1995 – 2003**

| 2003 / 1995 | Forest | R. Veg. | Crop & Settle | Bush/shrub | Woodland | Grassland | Total |
|---|---|---|---|---|---|---|---|
| Forest | 0 | 0.0 | -116 | -88 | 0.0 | -27 | **-231** |
| R. Veg. | 0.0 | 0 | -194 | -6 | 0.0 | -153 | **-353** |
| Crop & settle | 52 | 93 | 0 | 91 | 650 | 68 | **954** |
| Bush/shrub | 75 | 121 | -247 | 0 | 506 | 0.0 | **455** |
| Woodland | 0.0 | 0.0 | -257 | -93 | 0 | -48 | **-398** |
| Grassland | 24 | 21 | -143 | 0.0 | 114 | 0 | **16** |
| **Total** | **151** | **235** | **-957** | **-96** | **1,270** | **-160** | **443** |

Source: Own Computation upon Costanza et al., 1997 and Yun-guo et al., 2011

**Table 4.2e: ESV Gain/Loss of HRC (US$ '000') Estimated upon Change Matrices of LULC in 2003 – 2015**

| 2015 / 2003 | Forest | R. veg. | Crop & Settle | Bush/shrub | Woodland | Grassland | Total |
|---|---|---|---|---|---|---|---|
| Forest | 0 | 0.0 | -68 | -75 | 0.0 | -1 | **-144** |
| R. Vegetation | 0.0 | 0 | -180 | -72 | 0.0 | -4 | **-256** |
| Crop & settle | 23 | 150 | 0 | 96 | 622 | 9 | **900** |
| Bush/shrub | 26 | 97 | -173 | 0 | 45 | 0.0 | **-5** |
| Woodland | 0.0 | 0.0 | -522 | -370 | 0 | -7 | **-899** |
| Grassland | 22 | 89 | -167 | 0.0 | 441 | 0 | **385** |
| Total | **71** | **336** | **-1,110** | **-421** | **1,108** | **-3** | **-19** |

Source: Own Computation upon Costanza et al., 1997 and Yun-guo et al., 2011

**Table 4.2f: ESV Gain/Loss of HRC (US$ '000') Estimated upon Change Matrices of LULC in 1967 – 2015**

| 2015 / 1967 | Forest | R. Veg. | Crop & Set | Bush/shrub | Woodland | Grassland | Total (1967) |
|---|---|---|---|---|---|---|---|
| Forest | 0 | 0.0 | -1,543 | -178 | 0.0 | -159 | **-1,880** |
| R. Veg. | 0.0 | **0** | -1,556 | -323 | 0.0 | -9 | **-1,888** |
| Crop & set | 195 | 220 | **0** | 33 | 830 | 108 | **1,386** |
| Bush/shrub | 45 | 138 | -380 | **0** | 201 | 0.0 | **4** |
| Woodland | 0.0 | 0.0 | -3,893 | -803 | **0** | -106 | **-4,802** |
| Grassland | 52 | 41 | -133 | 0.0 | 181 | **0** | **141** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Total (2015)** | **292** | **399** | **-7,505** | **-1,271** | **1,212** | **-166** | **-7,039** |

**Source:** Computed upon Costanza et al., 1997 and Yun-guo et al., 2011;

**Table 4.4a: Level of ESV of HRC after Adjusting VC and Magnitude (M) of the ESV Changes**

| LULC | ESV (US$ '000') | | | | Magnitude of ESV Change (US$ '000') | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1967 | 1976 | 1985 | 1995 | 1967-1976 | | 1976-1985 | | 1985-1995 | |
| | | | | | M | % | M | % | M | % |
| Forest VC ±50% | 15043 | 8998 | 7072 | 6648 | -6045 | -40.2 | -1926 | -21.4 | -424 | -6.0 |
| | 12285 | 7852 | 6147 | 5673 | -4433 | -36.1 | -1705 | -21.7 | -474 | -7.7 |
| R. Vegetation VC±50% | 14893 | 9160 | 7451 | 6780 | -5733 | -38.5 | -1709 | -18.7 | -671 | -9.0 |
| | 12436 | 7690 | 5768 | 5540 | -4746 | -38.2 | -1922 | -25.0 | -228 | -4.0 |
| Cropland & settle VC±50% | 13920 | 8856 | 7227 | 6701 | -5064 | -36.4 | -1629 | -18.4 | -526 | -7.3 |
| | 13408 | 7994 | 5991 | 5619 | -5414 | -40.4 | -2003 | -25.1 | -372 | -6.2 |
| Bush/shrub VC±50% | 14137 | 9100 | 7066 | 6721 | -5037 | -35.6 | -2034 | -22.4 | -345 | -4.9 |
| | 13192 | 7750 | 6152 | 5600 | -5442 | -41.3 | -1598 | -20.6 | -552 | -9.0 |
| Woodland VC±50% | 16979 | 9947 | 7313 | 6614 | -7032 | -41.4 | -2634 | -26.5 | -699 | -9.6 |
| | 10349 | 6904 | 5905 | 5706 | -2835 | -41.4 | -999 | -14.5 | -199 | -3.4 |
| Grazing-land VC±50% | 13845 | 8702 | 6831 | 6577 | -5143 | -37.1 | -1871 | -21.5 | -254 | -3.7 |
| | 13483 | 8148 | 6388 | 5743 | -5335 | -39.6 | -1760 | -21.6 | -641 | -10.0 |
| ***Total[a]** | **13,664** | **8,425** | **6,609** | **6,160** | | | | | | |

*Total[a] = Total ESV before adjustment of VC of LULC classes by ±50% (**Source:** Own Calculation, 2017)

**Table 4.4b: Level of ESV (US$ '000') of HRC after Adjusting VC and Magnitude (M) of the ESV Changes**

| LULC Class | ESV (US$ '000') | | | | Magnitude of Change of ESV (US$ '000') | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1967 | 1995 | 2003 | 2015 | 1995-2003 | | 2003-2015 | | 1967-2015 | |
| | | | | | M | P (%) | M | P (%) | M | P (%) |
| Forest VC ±50% | 15043 | 6648 | 7045 | 6889 | 397 | 6.0 | -156 | -2.2 | -8154 | -54.2 |
| | 12285 | 5673 | 6181 | 6303 | 508 | 9.0 | 122 | 2.0 | -5982 | -48.7 |
| R. Vegetation VC±50% | 14893 | 6780 | 7010 | 7146 | 230 | 3.4 | 136 | 1.9 | -7747 | -52.0 |
| | 12436 | 5540 | 6217 | 6046 | 677 | 12.2 | -171 | -2.8 | -6390 | -51.4 |
| Crop & settle VC±50% | 13920 | 6701 | 7217 | 7277 | 516 | 7.7 | 60 | 0.8 | -6643 | -47.7 |
| | 13408 | 5619 | 6009 | 5915 | 390 | 6.9 | -94 | -1.6 | -7493 | -55.9 |
| Bush/shrub VC±50% | 14137 | 6721 | 6950 | 6933 | 229 | 3.4 | -17 | -0.3 | -7204 | -51.0 |
| | 13192 | 5600 | 6276 | 6259 | 676 | 12.1 | -17 | -0.3 | -6933 | -52.6 |
| Woodland VC±50% | 16979 | 6614 | 7771 | 7879 | 1157 | 17.5 | 108 | 1.4 | -9100 | -53.6 |
| | 10349 | 5706 | 5455 | 5313 | -251 | -4.4 | -142 | -2.6 | -5036 | -48.7 |
| Grazing-land VC±50% | 13845 | 6577 | 6992 | 6750 | 415 | 6.3 | -242 | -3.5 | -7095 | -51.2 |
| | 13483 | 5743 | 6234 | 6442 | 491 | 8.5 | 208 | 3.3 | -7041 | -52.2 |
| ***Total** | **13,664** | **6,160** | **6,613** | **6,596** | | | | | | |

***Total =** totalESV of HRC before VC were adjusted by 50%; **[Source:** Own Computation, 2017;

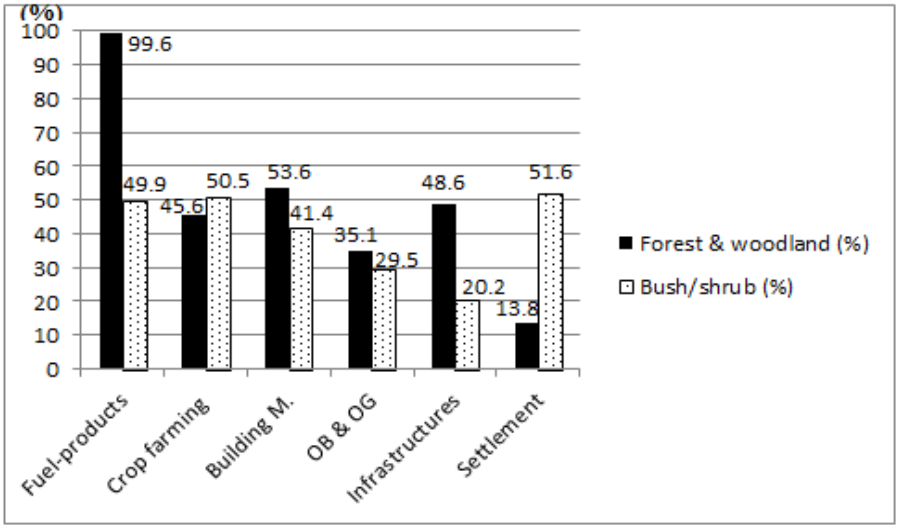


**Figure 4.3:** Causes for Decline of: **(a)** Forest & Woodland (that is the Black Bars), and **(b)** Bush/Shrub (that is the Grey Bars); [that is OB = Over Browsing; OG = Over Grazing]

**Table 4.5a Temperature (1987 – 2015) and Rainfall (1982 – 2015) Status in the LC & MC+UC of HRC**

| N0 | Variable | Measurement of Variable | LC | | MC+UC | |
|---|---|---|---|---|---|---|
| | | | Value | Period | Value | Period |
| I | Temperature | Maximum mean annual ($^0$C) | 25.1 | 2009 | 17.3 | 2008/2014 |
| | | Minimum mean annual ($^0$C) | 23.3 | 1998/2007 | 16.2 | 1998 |
| | | Range of mean annual ($^0$C) | 1.8 | 1987-2015 | 1.1 | 1987-2015 |
| | | Average of mean annual ($^0$C) | 24.0 | ” | 16.7 | ” |
| | | Standard deviation ($^0$C) | 0.41 | ” | 0.30 | ” |
| | | Coefficient of variation ($^0$C) | 0.0171 | ” | 0.0179 | ” |
| | | Change/rise in mean annual ($^0$C) | 0.6 | 1987-2015 | 0.5 | 1987-2015 |
| II | Rainfall | Maximum total annual (mm) | 1253.9 | 1997 | 1897.5 | 2007 |
| | | Minimum total annual (mm) | 580.1 | 1986 | 1135.2 | 1986 |
| | | Range of total annual (mm) | 673.8 | 1982-2015 | 762.3 | 1982-2015 |
| | | Mean total annual (mm) | 883.7 | ” | 1406.5 | ” |
| | | Standard deviation (mm) | 160.6 | ” | 168.7 | ” |
| | | Coefficient of variation (mm) | 0.182 | ” | 0.120 | ” |
| | | Change/rise of total annual (mm) | 214.8 | ” | 104.1 | ” |

**Source:** Own Computationupon Data from MAE (2016)

Table 4.5b Correlation b/n Time/Year, Average Annual Temperature (AAT), Rainfall & Discharge **(**$m^3$**),** HRC

| Variable | Measurement | Time/Year | AAT ($^0$C) | Annual RF (mm) | Discharge ($m^3$) |
|---|---|---|---|---|---|
| Time (year) | Pearson's "r" | 1 | | | |
| | Sig. (2-tailed) | | | | |
| | N | 34 | | | |
| AAT ($^0$C) | Pearson's "r" | 0.461** | 1 | | |
| | Sig. (2-tailed) | 0.005 | | | |
| | N | 34 | 34 | | |
| Annual Rainfall (mm) | Pearson's "r" | 0.519** | -0.111 | 1 | |
| | Sig. (2-tailed) | 0.001 | 0.520 | | |
| | N | 34 | 34 | 34 | |
| Annual discharge **(**m`$^3$**)** | Pearson's "r" | -0.200 | -0.258 | 0.033 | 1 |
| | Sig. (2-tailed) | 0.242 | 0.129 | 0.846 | |
| | N | 34 | 34 | 34 | 34 |

**. Correlation is significant at the 0.01 level (2-tailed) (**Source**: own computation, 2017)

**Table 4.6: "Value Coefficients" of broad and Specific Classes of Ecological Services in HRC**

| Ecosystem Services | | ESV (US$/ha/Year) of each LULC Class | | | | | |
|---|---|---|---|---|---|---|---|
| **Broad classes** | **Specific classes** | **Forest** | **River veg.** | **Cropland** | **Bush/shrub** | **Grass** | **Woodland** |
| Provisions | Water supply | 3 | 3 | - | - | - | 3 |
| | Food production | 43 | 43 | 54 | 67 | 67 | 43 |
| | Raw material | 138 | 138 | - | - | - | 138 |
| | Genetic resource | 16 | 16 | - | - | - | 16 |
| Regulatory | Water regulation | 2 | 2 | - | 2 | 2 | 2 |
| | Waste treatment | 87 | 87 | - | 87 | 87 | 87 |
| | Erosion control | 96 | 96 | - | 29 | 29 | 96 |
| | Climate regulation | 141 | 141 | - | - | - | 141 |
| | Biological control | 2 | 2 | 24 | 22 | 22 | 2 |
| | Gas regulation | - | - | - | 7 | 7 | - |
| | Disturbance regulation | 2 | 2 | - | - | - | 2 |
| Supportive | Nutrient cycling | 361 | 361 | - | - | - | 361 |
| | Pollination | - | - | 14 | 15 | 15 | - |
| | Soil formation | 10 | 10 | - | 1 | 1 | 10 |
| Cultural | Recreation | 66 | 66 | - | 2 | 2 | 66 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Cultural | 2 | 2 | - | - | - | 2 |
| Total | | 969 | 969 | 92 | 232 | 232 | 969 |

Source: Adapted from Costanza et al., 1997

## Appendix III: Produce, Revenue/Income, Input Costs, etc., of Croplands of HRC (Ch. 5)

**Table 5.1a Correlations (Pearson's) of farm inputs (land, ox power, labor, fertilizer, seedling and seed), HH size and age with "produce" & "revenue" from cropland in LC of HRC (2015/16)**

| | Produce | Land | Ox power | Labor | Fertilizer | Seedlings | Seeds | HH size | Revenue |
|---|---|---|---|---|---|---|---|---|---|
| Produce | 1 | | | | | | | | |
| Land | .855** | 1 | | | | | | | |
| | .000 | | | | | | | | |
| Ox power | .707** | .643** | 1 | | | | | | |
| | .000 | .000 | | | | | | | |
| Labor | .866** | .796** | .669** | 1 | | | | | |
| | .000 | .000 | .000 | | | | | | |
| Fertilizer | .700** | .626** | .499** | .631** | 1 | | | | |
| | .000 | .000 | .000 | .000 | | | | | |
| Seedlings | .452** | .307** | .272** | .322** | .298** | 1 | | | |
| | .000 | .001 | .008 | .001 | .003 | | | | |
| Seeds | .498** | .410** | .548** | .532** | .258** | .114 | 1 | | |
| | .000 | .000 | .000 | .000 | .003 | .235 | | | |
| HH size | .578** | .587** | .464** | .613** | .462** | .208* | .326** | 1 | |
| | .000 | .000 | .000 | .000 | .000 | .025 | .000 | | |
| Revenue | .924** | .790** | .711** | .812** | .667** | .439** | .505** | .524** | 1 |
| | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | |

**** = significant at 0.01 level (2-tailed); *= significant at 0.05 level (Source: own computation via SPSS, 2017)**

**Table 5.1b (i) Correlation (r) of Farm Inputs with Crop Produce and Revenue in MC of HRC, 2015/16**

| Variable | Tool | Produce | Land | Labor | Fertilizer | Seedling | Seed | HHS | Revenue |
|---|---|---|---|---|---|---|---|---|---|
| Produce | Pearson "r" | 1 | | | | | | | |
| | Sig. (2-t) | | | | | | | | |
| Land | Pearson "r" | .74** | 1 | | | | | | |
| | Sig. (2-t) | .000 | | | | | | | |
| Labor | Pearson "r" | .76** | .60** | 1 | | | | | |
| | Sig. (2-t) | .000 | .000 | | | | | | |
| Fertilizer | Pearson "r" | .61** | .53** | .54** | 1 | | | | |
| | Sig. (2-t) | .000 | .000 | .000 | | | | | |
| Seedling | Pearson "r" | .66** | .45** | .55** | .38** | 1 | | | |
| | Sig. (2-t) | .000 | .000 | .000 | .003 | | | | |
| Seed | Pearson "r" | .66** | .49** | .54** | .37** | .43** | 1 | | |
| | Sig. (2-t) | .000 | .000 | .000 | .000 | .000 | | | |
| HH Size | Pearson "r" | .37** | .32** | .30** | .32** | .42** | .34** | 1 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Revenue | Sig. (2-t) | .000 | .000 | .001 | .001 | .000 | .000 | | |
| | Pearson "r" | .83** | .65** | .63** | .59** | .50** | .51** | .42** | 1 |
| | Sig. (2-t) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | |

**. Correlation is significant at 0.01 level (2-tailed).**(Source: own computation via SPSS, 2017)**

**Table 5.1b (ii)Correlation (r) of Farm Inputs with Crop Produceand Revenue in UC of HRC, 2015/16**

| Variable | Tool | Produce | Land | Labor | Fertilizer | Seedling | Seed | HHS | Revenue |
|---|---|---|---|---|---|---|---|---|---|
| Produce | Pearson "r" | 1 | | | | | | | |
| | Sig. (2-t) | | | | | | | | |
| Land | Pearson "r" | .92** | 1 | | | | | | |
| | Sig. (2-t) | .000 | | | | | | | |
| Labor | Pearson "r" | .94** | .86** | 1 | | | | | |
| | Sig. (2-t) | .000 | .000 | | | | | | |
| Fertilizer | Pearson "r" | .86** | .77** | .85** | 1 | | | | |
| | Sig. (2-t) | .000 | .000 | .000 | | | | | |
| Seedling | Pearson "r" | .85** | .83** | .78** | .73** | 1 | | | |
| | Sig. (2-t) | .000 | .000 | .000 | .000 | | | | |
| Seed | Pearson "r" | .94** | .87** | .91** | .81** | .79** | 1 | | |
| | Sig. (2-t) | .000 | .000 | .000 | .000 | .000 | | | |
| HH Size | Pearson "r" | .52** | .46** | .49** | .34** | .38** | .57** | 1 | |
| | Sig. (2-t) | .000 | .000 | .000 | .000 | .001 | .000 | | |
| Revenue | Pearson "r" | .91** | .88** | .86** | .76** | .79** | .89** | .48** | 1 |
| | Sig. (2-t) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | |

**. Correlation is significant at 0.01 level (2-tailed).**(Source: own computation via SPSS, 2017)**

**Table 5.1c Correlations (Pearson's) of farm inputs (land, labor, fertilizer, seedling and seed) with level of "produce" of cropland in the Whole HRC, 2015/16**

| Variable | Measure | Produce | Land | Labor | Fertilizer | Seedling | Seed |
|---|---|---|---|---|---|---|---|
| Produce | Pearson corr. | 1 | | | | | |
| | Sig. (2-tailed) | | | | | | |
| Land | Pearson corr. | .855** | 1 | | | | |
| | Sig. (2-tailed) | .000 | | | | | |
| Labor | Pearson corr. | .754** | .719** | 1 | | | |
| | Sig. (2-tailed) | .000 | .000 | | | | |
| Fertilizer | Pearson corr. | .634** | .587** | .669** | 1 | | |
| | Sig. (2-tailed) | .000 | .000 | .000 | | | |
| Seedling | Pearson corr. | .617** | .538** | .479** | .424** | 1 | |
| | Sig. (2-tailed) | .000 | .000 | .000 | .000 | | |
| Seed | Pearson corr. | .280** | .284** | .555** | .423** | .208** | 1 |
| | Sig. (2-tailed) | .000 | .000 | .000 | .000 | .001 | |

**. Correlation is significant at the 0.01 level (2-tailed).**(Source: own computation via SPSS-version 20, 2017)**

**Table 5.1d: ANOVA about the Level of Crop Harvest/Produce of the LC in 2015/16 upon Difference in Farmland, Gender, Labor, HH Size and Fertilizer Use among Farmers of the Sub-catchment (LC), HRC**

| Variable | Measurement | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Produce * Farmland (One-way ANOVA) | Between groups | 2553.220 | 9 | 283.691 | 53.896 | .000 |
| | Within groups | 863.240 | 164 | 5.264 | | |
| | Total | 3416.460 | 173 | | | |
| Produce * Gender (Mean Comparison) | Between groups | 70.323 | 1 | 70.323 | 3.615 | .059 |
| | Within groups | 3346.137 | 172 | 19.454 | | |
| | Total | 3416.460 | 173 | | | |
| Produce * Labor (One-way ANOVA) | Between groups | 2753.789 | 11 | 250.344 | 60.527 | .000 |
| | Within groups | 653.505 | 158 | 4.136 | | |
| | Total | 3407.294 | 169 | | | |
| Produce * HH size (One-way ANOVA) | Between groups | 1386.209 | 3 | 462.070 | 38.691 | .000 |
| | Within groups | 2030.251 | 170 | 11.943 | | |
| | Total | 3416.460 | 173 | | | |
| Produce*Fertilizer (One-way ANOVA) | Between groups | 1499.137 | 8 | 187.392 | 21.617 | .000 |
| | Within groups | 1031.582 | 119 | 8.669 | | |
| | Total | 2530.719 | 127 | | | |

*. Variation is significant at the 0.05 level (2-tailed), **Source**: Computed via SPSS (Version 20), 2016/17

**Table 5.1e: ANOVA about Income/Revenue from Croplands of the LC in 2015/16 upon Difference in Farmland, Gender and HH Size among Farmers of the Sub-catchment (LC), HRC**

| Variable | Measurement | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Revenue * Farmland (One-way ANOVA) | Between groups | 1171.281 | 9 | 130.142 | 34.339 | 0.000 |
| | Within groups | 621.546 | 164 | 3.790 | | |
| | Total | 1792.828 | 173 | | | |
| Revenue * Gender (Mean Comparison) | Between groups | 52.811 | 1 | 52.811 | 5.220 | 0.024 |
| | Within groups | 1740.017 | 172 | 10.116 | | |
| | Total | 1792.828 | 173 | | | |
| Revenue * HH size (One-way ANOVA) | Between groups | 632.174 | 3 | 210.725 | 30.865 | 0.000 |
| | Within groups | 1160.654 | 170 | 6.827 | | |
| | Total | 1792.828 | 173 | | | |

*. Variation is significant at the 0.05 level (2-tailed); **Source**: Own Computation via SPSS (Version 20), 2016/17

**Table 5.1f (i):** ANOVA on Average Crop Harvest upon Difference in Gender, HH-Size, Farm-Size, Labor and Fertilizer Amount Used for Cultivation by HH of the MC, 2015/16

| 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 | .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 | .000 |
| | | Within groups | 269.686 | 103 | 2.618 | | |
| | | Total | 451.107 | 111 | | | |

*****Significant at 0.05 level (2-tailed).**Source**: Own Computation (2018) upon Own Survey Data (2016-2017)

**Table 5.1f (ii):**ANOVA of Average Crop Revenue upon Difference in Gender, HH-Size, Farm-Size, Labor and Fertilizer Amount Used for Cultivation by HH of the MC, 2015/16

| N0 | Variable/Factor | Measurement | Sum of Squares | df | Mean$^2$ | F | Sig |
|---|---|---|---|---|---|---|---|
| I | Crop revenue*gender (Mean Comparison) | Between groups | 25.607 | 1 | 25.607 | 18.693 | .000 |
| | | Within groups | 180.819 | 132 | 1.370 | | |
| | | Total | 206.425 | 133 | | | |
| II | Crop revenue *HH-size (One-way ANOVA) | Between groups | 37.336 | 3 | 12.445 | 9.568 | .000 |
| | | Within groups | 169.090 | 130 | 1.301 | | |
| | | Total | 206.426 | 133 | | | |
| III | Crop revenue *farm-size (One-way ANOVA) | Between groups | 90.716 | 5 | 18.143 | 20.070 | .000 |
| | | Within groups | 115.710 | 128 | 0.904 | | |
| | | Total | 206.426 | 133 | | | |
| IV | Crop revenue *labor (One-way ANOVA) | Between groups | 92.677 | 11 | 8.425 | 9.218 | .000 |
| | | Within groups | 107.853 | 118 | 0.914 | | |
| | | Total | 200.531 | 129 | | | |
| V | Crop revenue *fertilizer (One-way ANOVA) | Between groups | 63.327 | 8 | 7.916 | 7.666 | .000 |
| | | Within groups | 106.352 | 103 | 1.033 | | |
| | | Total | 169.679 | 111 | | | |

*****Significant at 0.05 level (2-tailed).**Source**: Own Computation (2018) upon Own Survey Data (2016-2017)

**Table 5.1g (i):** ANOVA of Average Crop Revenue upon Difference in Gender, HH-Size, Farm-Size, Labor and Fertilizer Amount Used for Cultivation by HH of the UC, 2015/16

| N0 | Variable/Factor | Measurement | Sum of Squares | df | Mean$^2$ | F | Sig |
|---|---|---|---|---|---|---|---|
| I | Crop harvest*gender | Between groups | 158.296 | 1 | 158.296 | 13.687 | .000 |
| | (Mean Comparison) | 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 |
| | (One-way ANOVA) | 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 |
| | (One-way ANOVA) | 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 |
| | (One-way ANOVA) | Within groups | 66.811 | 139 | .481 | | |
| | | Total | 1890.172 | 150 | | | |
| V | Crop harvest*fertilizer | Between groups | 1150.827 | 8 | 143.853 | 45.557 | .000 |
| | (One-way ANOVA) | Within groups | 296.823 | 94 | 3.158 | | |
| | | Total | 1447.650 | 102 | | | |

*****Significant at 0.05 level (2-tailed).**Source**: Own Computation (2018) upon Own Survey Data (2016-2017)

**Table 5.1g (ii):** ANOVA of Average Crop Revenue upon Difference in Gender, HH-Size, Farm-Size, Labor and Fertilizer Amount Used for Cultivation by HH of the UC, 2015/16 (sig at 0.05 level)

| N0 | Variable/Factor | Measurement | Sum of Squares | df | Mean$^2$ | F | Sig |
|---|---|---|---|---|---|---|---|
| I | Crop revenue*gender | Between groups | 34.793 | 1 | 34.793 | 11.404 | .001 |
| | (Mean Comparison) | Within groups | 472.901 | 155 | 3.051 | | |
| | | Total | 507.694 | 156 | | | |
| II | Crop revenue *HH-size | Between groups | 132.415 | 3 | 44.138 | 17.995 | .000 |
| | (One-way ANOVA) | Within groups | 375.280 | 153 | 2.453 | | |
| | | Total | 507.694 | 156 | | | |
| III | Crop revenue *farm-size | Between groups | 397.443 | 7 | 56.778 | 76.733 | .000 |
| | (One-way ANOVA) | Within groups | 110.251 | 149 | .740 | | |
| | | Total | 507.694 | 156 | | | |
| IV | Crop revenue *labor | Between groups | 401.667 | 11 | 36.515 | 57.780 | .000 |
| | (One-way ANOVA) | Within groups | 87.843 | 139 | .632 | | |
| | | Total | 489.510 | 150 | | | |
| V | Crop revenue *fertilizer | Between groups | 226.943 | 8 | 28.368 | 20.703 | .000 |
| | (One-way ANOVA) | Within groups | 128.804 | 94 | 1.370 | | |
| | | Total | 355.748 | 102 | | | |

**Source**: Own Computation (2018) upon Own Survey Data (2016-2017)

**Table 5.1h: One-Way ANOVA about Crop "Produce" upon Differences in Farm-size, Gender, Labor, HH Size and Fertilizer Use among Farmers of the Whole HRC in 2015/16**

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

* At 95% confidence level; **Source**: Own Computation via SPSS (Version 20) upon HH Survey Data, 2016/17

Table 5.5a Ecosystem Service Value (ESV) of Hare in 1967, 1976, 1985, 1995, 2003 & 2015

| LULC Class | Annual ESV in US$ ('000') | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1967 | | 1976 | | 1985 | | 1995 | | 2003 | | 2015 | |
| | ESV | P (%) | ESV | P (%) | ESV | P (%) | ESV | P (%) | ESV | P (%) | ESV | P (%) |
| Forest | 2,758 | 20.2 | 1,146 | 13.6 | 925 | 14.0 | 975 | 15.8 | 864 | 13.0 | 586 | 8.9 |
| Riverine vegetation | 2,457 | 18.0 | 1,470 | 17.5 | 1,683 | 25.5 | 1,240 | 20.1 | 793 | 12.0 | 1,100 | 16.7 |
| Cropland & settle* | 512 | 3.7 | 862 | 10.2 | 1,236 | 18.7 | 1,082 | 17.6 | 1,208 | 18.3 | 1,362 | 20.6 |
| Bush/shrub | 945 | 6.9 | 1,350 | 16.0 | 914 | 13.8 | 1,121 | 18.2 | 674 | 10.2 | 674 | 10.2 |
| Woodland | 6,630 | 48.5 | 3,043 | 36.1 | 1,408 | 21.3 | 908 | 14.8 | 2,316 | 35.0 | 2,566 | 38.9 |
| Grazing | 362 | 2.7 | 554 | 6.6 | 443 | 6.7 | 834 | 13.5 | 758 | 11.5 | 308 | 4.7 |
| Total | **13664** | **100** | **8,425** | **100** | **6,609** | **100** | **6,160** | **100** | **6,613** | **100** | **6,596** | **100** |

Source: Own Computation, 2017. * Settle = Settlement

**Table 5.1i: One-Way ANOVA about "Revenue" from Crop Harvest upon Differences in Farm-size, Gender, Labor, HH Size and Fertilizer Use among Farmers of the Whole HRC in 2015/16**

| Variable | Measurement | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Revenue * Farm-size | Between Groups | 1905.697 | 9 | 211.744 | 88.510 | .000 |
| | Within Groups | 1088.510 | 455 | 2.392 | | |
| | Total | 2994.206 | 464 | | | |
| Revenue * Gender (MC) | Between Groups | 115.268 | 1 | 115.268 | 18.538 | .000 |
| | Within Groups | 2878.939 | 463 | 6.218 | | |
| | Total | 2994.206 | 464 | | | |
| Revenue * Labor | Between Groups | 1315.926 | 12 | 109.660 | 29.724 | .000 |
| | Within Groups | 1615.893 | 438 | 3.689 | | |
| | Total | 2931.818 | 450 | | | |
| Revenue * HH size | Between Groups | 323.996 | 3 | 107.999 | 18.904 | .000 |
| | Within Groups | 2627.995 | 460 | 5.713 | | |
| | Total | 2951.991 | 463 | | | |
| Revenue * Fertilizer | Between Groups | 697.253 | 8 | 87.157 | 18.039 | .000 |
| | Within Groups | 1613.721 | 334 | 4.831 | | |
| | Total | 2310.974 | 342 | | | |

* At 95% confidence level; **Source**: Own Computation via SPSS (Version 20) upon HH Survey Data, 2016/17

**Table 5.5b: Area (ha) of the Six LULC Classes of HRC in 1967 – 2015**

| N0 | LUC | 1967 | 1976 | 1985 | 1995 | 2003 | 2015 |
|---|---|---|---|---|---|---|---|
| | | Area (ha) | Area (ha) | Area (ha) | Area (ha) | Area (ha) | Area (ha) |
| 1 | Forest | 2846.1 | 1183.1 | 955 | 1006.2 | 892.0 | 605.1 |
| 2 | Riverine vegetation | 2535.2 | 1517.8 | 1737.5 | 1280.0 | 818.6 | 1135.3 |
| 3 | Cropland & settlement | 5567.1 | 9380.3 | 13435.7 | 11769.1 | 13140.9 | 14808.2 |
| 4 | Bush/shrub | 4072.3 | 5821.4 | 3943.0 | 4832.4 | 2909.2 | 2907.5 |
| 5 | Woodland | 6850.0 | 3139.7 | 1449.4 | 948.0 | 2401.8 | 2646.7 |
| 6 | Grazing-land | 1562.0 | 2390.4 | 1912.4 | 3597.2 | 3270.2 | 1330.0 |

**Source:** Analysis via ERDAS Imagine 3.8 and Arc GIS 9.3

**Table 5.6a: Independent Sample T-test for Comparison between HH of the LC Vs., MC upon Mean Farm-size (ha/HH), Produce (Quintal/HH), Labor (#/HH), Fertilizer (kg/HH) and Seedlings (#/HH) used for Cultivation, and Mean Value/Revenue/Income (US$/HH) of Crop Harvest, HRC (2015/16)**

| Variable | Assump | Levene's TEV | | T-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | F | Sig | t | df | Sig (2t) | MD | Std. ED | 95% CI of Difference | |
| | | | | | | | | | Lower B | Upper B |
| Farm-size (ha) | EVA | 34.07 | 0.000 | 5.48 | 305 | 0.000 | 1.112 | 0.20 | 0.71 | 1.51 |
| | EVNA | | | 5.83 | 291.96 | 0.000 | 1.112 | 0.19 | 0.74 | 1.49 |
| Produce (Q) | EVA | 38.73 | 0.000 | 6.93 | 305 | 0.000 | 2.867 | 0.41 | 2.05 | 3.68 |
| | EVNA | | | 7.58 | 252.34 | 0.000 | 2.87 | 0.38 | 2.12 | 3.61 |
| Labor (#/HH) | EVA | 2.99 | 0.084 | -1.45 | 297 | 0.148 | -0.47 | 0.32 | -1.11 | 0.17 |
| | EVNA | | | -1.47 | 289.86 | 0.141 | -0.47 | 0.32 | -1.10 | 0.16 |
| Fertilizer (kg) | EVA | 0.40 | 0.529 | -0.31 | 237 | 0.760 | -0.07 | 0.24 | -0.55 | 0.40 |
| | EVNA | | | -0.30 | 224.39 | 0.762 | -0.07 | 0.24 | -0.55 | 0.41 |
| Seedling (#/HH) | EVA | 10.70 | 0.001 | 4.62 | 181 | 0.000 | 4.33 | 0.94 | 2.48 | 6.18 |
| | EVNA | | | 5.01 | 173.35 | 0.000 | 4.33 | 0.86 | 2.62 | 6.04 |
| Seeds (kg/HH) | EVA | 101.98 | 0.000 | -16.83 | 299 | 0.000 | -18.54 | 1.10 | -20.70 | -16.37 |
| | EVNA | | | -15.46 | 165.46 | 0.000 | -18.54 | 1.20 | -20.90 | -16.17 |
| Value (US$) | EVA | 54.38 | 0.000 | 7.62 | 306 | 0.000 | 2.238 | 0.29 | 1.66 | 2.82 |
| | EVNA | | | 8.39 | 235.26 | 0.000 | 2.238 | 0.27 | 1.71 | 2.76 |

*At 95% confidence interval (Recall: Assum = Assumption, TEV = Test for Equality of Variance; EVA = Equality of Variance Assumed; and EVNA = Equality of Variance Not Assumed) (Source: Analysis via SPSS-version 20, 2017)

**Table 5.6b: Independent Sample T-test for Comparison between HH of the LC Vs., UC upon Mean Farm-size (ha/HH), Produce (Quintal/HH), Labor (#/HH), Fertilizer (kg/HH) and Seedlings (#/HH) used for Cultivation, and Mean Value/Revenue/Income (US$/HH) of Crop Harvest, HRC (2015/16)**

| Variable | Assump | Levene's TEV | | T-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | F | Sig | t | df | Sig (2t) | MD | Std. ED | 95% CI of Difference | |
| | | | | | | | | | Lower B | Upper B |
| Farm-size (ha) | EVA | 4.39 | 0.037 | 2.95 | 330 | 0.003 | 0.62 | 0.21 | 0.21 | 1.03 |
| | EVNA | | | 2.98 | 327.63 | 0.003 | 0.62 | 0.21 | 0.21 | 1.03 |
| Produce (Q) | EVA | 45.88 | 0.000 | 9.06 | 329 | 0.000 | 6.35 | 0.70 | 4.97 | 7.72 |
| | EVNA | | | 9.38 | 241.73 | 0.000 | 6.35 | 0.67 | 5.01 | 7.68 |
| Labor (#/HH) | EVA | 0.01 | 0.936 | -3.37 | 320 | 0.001 | -1.09 | 0.32 | -1.73 | -0.45 |
| | EVNA | | | -3.37 | 317.34 | 0.001 | -1.09 | 0.32 | -1.73 | -0.46 |
| Fertilizer (kg) | EVA | 16.51 | 0.000 | -1.66 | 230 | 0.098 | -0.45 | 0.27 | -0.99 | 0.08 |
| | EVNA | | | -1.61 | 185.84 | 0.109 | -0.45 | 0.28 | -1.01 | 0.10 |
| Seedling (#/HH) | EVA | 5.15 | 0.024 | 0.35 | 195 | 0.728 | 0.37 | 1.06 | -1.71 | 2.45 |
| | EVNA | | | 0.34 | 155.17 | 0.735 | 0.37 | 1.09 | -1.78 | 2.51 |
| Seeds (kg/HH) | EVA | 112.92 | 0.000 | -9.63 | 324 | 0.000 | -10.16 | 1.06 | -12.24 | -8.09 |
| | EVNA | | | -9.43 | 206.69 | 0.000 | -10.16 | 1.08 | -12.29 | -8.04 |
| Value (US$) | EVA | 28.11 | 0.000 | 6.85 | 329 | 0.000 | 1.99 | 0.29 | 1.42 | 2.57 |
| | EVNA | | | 7.03 | 277.15 | 0.000 | 1.99 | 0.28 | 1.44 | 2.55 |

*At 95% confidence interval (Recall: Assum = Assumption, TEV = Test for Equality of Variance; EVA = Equality of Variance Assumed; and EVNA = Equality of Variance Not Assumed) (Source: Analysis via SPSS-version 20, 2017)

**Table 5.6c: Independent Sample T-test for Comparison between HH of the MC Vs., UC upon Mean Farm-size (ha/HH), Produce (Quintal/HH), Labor (#/HH), Fertilizer (kg/HH) and Seedlings (#/HH) used for Cultivation, and Mean Value/Revenue/Income (US$/HH) of Crop Harvest, HRC (2015/16)**

| Variable | Assump | Levene's TEV | | T-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | F | Sig | t | df | Sig (2t) | MD | Std. ED | 95% CI of Difference | |
| | | | | | | | | | Lower B | Upper B |
| Farm-size (ha) | EVA | 17.59 | 0.000 | -2.75 | 289 | .006 | -0.49 | 0.18 | -0.85 | -0.14 |
| | EVNA | | | -2.82 | 283.87 | .005 | -0.49 | 0.18 | -0.84 | -0.15 |
| Produce (Q) | EVA | 37.98 | 0.000 | -2.54 | 289 | .012 | -0.87 | 0.34 | -1.55 | -0.20 |
| | EVNA | | | -2.66 | 254.31 | .008 | -0.87 | 0.33 | -1.52 | -0.23 |
| Labor (#/HH) | EVA | 2.77 | 0.097 | -1.88 | 279 | .061 | -0.62 | 0.33 | -1.27 | 0.03 |
| | EVNA | | | -1.90 | 277.83 | .050 | -0.62 | 0.33 | -1.26 | 0.02 |
| Fertilizer (kg) | EVA | 9.48 | 0.002 | -1.28 | 213 | .201 | -0.38 | 0.30 | -0.97 | 0.20 |
| | EVNA | | | -1.28 | 199.20 | .204 | -0.38 | 0.30 | -0.97 | 0.21 |
| Seedling (#/HH) | EVA | 25.82 | 0.000 | -3.56 | 148 | .000 | -3.96 | 1.11 | -6.16 | -1.76 |
| | EVNA | | | -3.72 | 136.78 | .000 | -3.96 | 1.07 | -6.07 | -1.85 |
| Seeds (kg/HH) | EVA | 0.04 | 0.847 | 5.57 | 289 | .000 | 8.37 | 1.50 | 5.41 | 11.33 |
| | EVNA | | | 5.55 | 277.06 | .000 | 8.37 | 1.51 | 5.40 | 11.34 |
| Value (US$) | EVA | 13.53 | 0.000 | -1.43 | 289 | .154 | -0.26 | 0.19 | -0.63 | 0.10 |
| | EVNA | | | -1.47 | 277.64 | .143 | -0.26 | 0.18 | -0.62 | 0.09 |

*At 95% confidence interval (Recall: Assump = Assumption, TEV = Test for Equality of Variance; EVA = Equality of Variance Assumed; and EVNA = Equality of Variance Not Assumed) (Source: Analysis via SPSS-version 20, 2017)

**Table 5.6d**: One-Way ANOVA about Level of Crop Harvest/Produce upon Difference in: **(I)** Fertilizer Use, and **(II)** Farm-size among HH of the Whole HRC in 2015/16

| N0 | Measure | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| I | Between Groups | 2197.048 | 8 | 274.631 | 30.751 | .000 |
| | Within Groups | 2982.847 | 334 | 8.931 | | |
| | Total | 5179.895 | 342 | | | |
| II | Between Groups | 4884.553 | 9 | 542.728 | 146.898 | .000 |
| | Within Groups | 1681.038 | 455 | 3.695 | | |
| | Total | 6565.591 | 464 | | | |

* At 95% level of confidence (**Source:** Own Analysis via SPSS-version 20, 2017)

**Table 5.6e: One-way ANOVA about Level of Crop Produce & Its Revenue, and Labor, fertilizer, Seeds & Seedlings Amount Used for 2015/16 Cultivation upon Difference in "Farm size" among HH of HRC**

| Variable | | Sum of Squares | df | Mean$^2$ | F | Sig. |
|---|---|---|---|---|---|---|
| Produce | Between groups | 5612.589 | 14 | 400.899 | 189.301 | .000 |
| | Within groups | 953.002 | 450 | 2.118 | | |
| | Total | 6565.591 | 464 | | | |
| Labor | Between groups | 2310.397 | 14 | 165.028 | 57.564 | .000 |
| | Within groups | 1249.949 | 436 | 2.867 | | |
| | Total | 3560.346 | 450 | | | |
| Fertilizer | Between groups | 611.435 | 14 | 43.674 | 18.098 | .000 |
| | Within groups | 791.522 | 328 | 2.413 | | |
| | Total | 1402.956 | 342 | | | |
| Seedlings | Between groups | 5454.205 | 13 | 419.554 | 14.170 | .000 |
| | Within groups | 7431.531 | 251 | 29.608 | | |
| | Total | 12885.736 | 264 | | | |
| Seeds | Between groups | 13770.269 | 14 | 983.591 | 6.834 | .000 |
| | Within groups | 63901.173 | 444 | 143.922 | | |
| | Total | 77671.442 | 458 | | | |
| Revenue | Between groups | 1913.202 | 9 | 212.578 | 89.981 | 0.000 |
| | Within groups | 1074.927 | 455 | 2.362 | | |
| | Total | 2988.129 | 464 | | | |

* At 95% level of confidence **(Source:** Own Analysis via SPSS-version 20, 2017)

**Table 5.7a: Proportion (%), Average, Per Capita Income andNet Economic Value (NEV) from Crop Harvest, and Cost of Farm InputsUsed by HH for 2015/16 Harvest Season in HRC**

| N0 | Measurement | LC | MC | UC | MC+UC | HRC |
|---|---|---|---|---|---|---|
| 1 | Amount (quintal) of crop produce, (%) | 64.3 | 14.4 | 21.3 | 35.7 | 100 |
| 2 | Income(US$) from crop produce, (%) | 52.3 | 20.7 | 27.0 | 47.7 | 100 |
| 3 | NEV (US$) from crop produce, (%) | 53.0 | 20.4 | 26.6 | 47.0 | 100 |
| 4 | Cost (US$) of inputs for crop harvest, (%) | 45 | 24 | 31 | 55 | 100 |
| 5 | Average crop produce (quintal/HH/Year) | 35.4 | 10.3 | 13.0 | 11.8 | 20.6 |
| 6 | Average income from produce (US$/HH/Year) | 971.4 | 499.3 | 556.5 | 530.2 | 695.3 |
| 7 | Per capita income from produce (US$/P/Year) | 194.3 | 99.9 | 111.3 | 106.1 | 139.1 |
| 8 | Average NEV ofcrop produce (US$/HH/Year) | 893.1 | 445.0 | 496.6 | 472.8 | 630.1 |
| 9 | Per capita NEV of crop produce (US$/P/Year) | 178.6 | 89.0 | 99.3 | 94.6 | 126.0 |
| 10 | Average cost of inputs for harvest (US$/HH/Y) | 78.4 | 54.4 | 59.9 | 57.4 | 65.2 |
| 11 | Sample HH | 174 | 134 | 157 | 291 | 465 |

**Source**: Own Computation (2018) upon Own Survey Data (2016 – 2017) [*Total Crop Produce of HRC = 9,588.8Q; Gross Income = US$ 323,310; NEV = US$ 292,985.3; Farm Inputs Cost = US$ 30,324.7]

**Table 5.7b Maximum, Minimum and Mean Produce and Income from Croplands of HRC (2015/16)**

| Category | Crop Produce (Q/HH/Yr) | | | | Value/Income/Revenue in US$ (ETB)/HH/Year | | | |
|---|---|---|---|---|---|---|---|---|
| | Max | Min | Range | Mean | Max | Min | Range | Mean |
| LC | 119 | 5 | 114 | 35.4 | 3,854.8 (82,879) | 170.3 (3,661) | 3684.5 (79,216.8) | 971.4 (20,885.1) |
| MC | 32 | 2 | 30 | 10.3 | 1,394.7 (29,986) | 98.7 (2,123) | 1,296.0 (27,863) | 499.3 (10,735.0) |
| UC | 44 | 2 | 42 | 13.0 | 1,842.1 (39,604) | 110.7 (2,379) | 1,731.4 (37,225) | 556.5 (11,964.8) |
| MC+UC | 44 | 2 | 42 | 11.8 | 1,842.1 (39,604) | 98.7 (2,123) | 1,743.4 (37,483) | 530.2 (11,399.3) |
| HRC | 119 | 2 | 117 | 20.6 | 3,854.8 (82,878) | 98.7 (2,123) | 3,756.1 (80,755) | 695.3 (14,949.0) |

**Source**: Computed (2017) upon Own HH Survey (2016 – 2017) Data (Max=Maximum, Min=Minimum)

**Table 5.8a Mean Monthly Temperature (MT) Averaged for 29 Years (1987 - 2015) and Mean Total Monthly Rainfall (MRF) for 34 Years (1982 - 2015) in LC and MUC of HRC**

| Category | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LC_MT ($^0$C) | 24.4 | 25.3 | 25.9 | 24.7 | 24.2 | 23.9 | 23.3 | 23.8 | 23.7 | 23.4 | 22.9 | 22.8 | 24.0 |
| LC_MRF (mm) | 28.9 | 32.1 | 59.6 | 153.7 | 152.1 | 60.5 | 43.6 | 50.4 | 90.4 | 115.6 | 62.1 | 34.7 | 883.7 |
| MUC_MT ($^0$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_MRF (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: Own Computation (2017) upon Data of Meteorological Agency, Ethiopia (MUC = Middle and Upper Catchment)**

**Table 5.8b: Values of Selected Temperature ($^0$C) and Rainfall Attributes of HRC within a Year**

| N0 | Measurement | Temperature ($^0$C) | | Rainfall (mm) | |
|---|---|---|---|---|---|
| | | LC | MUC | LC | MUC |
| 1 | Mean annual | 24.0 | 16.7 | 73.64 | 117.2 |
| 2 | Annual range | 3.1 | 3.7 | 124.8 | 202.1 |
| 2 | Standard deviation | 0.9 | 1.2 | 37.3 | 60.8 |
| 3 | Coefficient of variation | 0.0375 | 0.0719 | 0.507 | 0.519 |
| 4 | Total annual | - | - | 883.7 | 1406.5 |

**Source:** Own Computation (2017) upon Mean Annual Temperature (1987 - 2015) and Mean Total Annual Rainfall (1982 - 2015) of HRC (MAE, 2016) (**MUC** = **Middle and Upper Catchment**)

**Table 5.9a Average Unit Cost (AUC) and Total Cost (TC) of Seeds & Seedlings Used for 2015/16 Harvest in LC**

| N0 | Seeds/ Seedlings | HH | | Input Amount | | AUC and TC (ETB & US$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | P (%) | Mean | Total | AUC (ETB) | TC (ETB) | TC (US$) | P (%) |
| 1 | Banana (#)* | 54 | 31.0 | 33.0 | 1,782.0 | 6.1 | 10,870.2 | 505.6 | |
| 2 | Mango (#)* | 51 | 29.3 | 20.0 | 1,020.0 | 7.1 | 7,242.0 | 336.8 | |
| 3 | Maize (kg)** | 67 | 38.5 | 17.3 | 1,159.1 | 10.9 | 12,634.2 | 587.6 | |
| 4 | Onion (kg)** | 46 | 26.4 | 19.7 | 907.6 | 6.0 | 5,445.6 | 253.3 | |
| | **Total** | | | | | | | **1,683.3** | **100.0** |

Source: Computed upon Own HH Survey Data, 2016/17 (**Recall**: * = Seedlings; ** = Seeds)

**Table 5.9b Cost of Seeds and Seedlings Used by HH of the MC of Hare for 2015/16 production Season**

| N0 | Seeds/Seedlings | HH | | Input Amount | | Cost (in ETB and US$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | P (%) | Mean | Total | AUC (ETB) | ETB | US$ | P (%) |
| 1 | Barley (kg)** | 41 | 30.6 | 23.3 | 955.3 | 9.4 | 8,979.8 | 417.7 | |
| 2 | Wheat (kg)** | 34 | 25.4 | 15.1 | 513.4 | 12.5 | 6,417.5 | 298.5 | |
| 3 | Apple (#)* | 20 | 14.9 | 32.0 | 640.0 | 26.4 | 16,896.0 | 785.9 | |
| 4 | Bean (kg)** | 22 | 16.4 | 14.3 | 314.6 | 12.4 | 3,901.0 | 181.4 | |
| 5 | Pea (kg)** | 20 | 14.9 | 12.7 | 254.0 | 16.6 | 4,216.4 | 196.1 | |
| 6 | Potato (kg)** | 42 | 31.3 | 29.6 | 1,243.2 | 3.4 | 4,226.9 | 196.6 | |
| | **Total** | - | - | - | - | - | | | **100.0** |

**Source**: Own HH Survey Data, 2016/17 (**Recall**: * = Seedlings; ** = Seeds; AUC = Average Unit Cost)

**Table 5.9c Cost of Seeds & Seedling Used by HH of the UC of Hare for 2015/16 Production Season**

| N0 | Category | HH | | Amount (in Kg/#) | | Cost (in ETB and US$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | P (%) | Mean | Total | AUC (ETB) | ETB | US$ | P (%) |
| **1** | Barley (kg)** | 47 | 29.9 | 21.8 | 1.024.6 | 9.6 | 9.836.2 | 457.5 | |
| **2** | Wheat (kg)** | 32 | 20.4 | 17.3 | 553.6 | 13.0 | 1,196.8 | 334.7 | |
| **3** | Bean (kg)** | 21 | 13.4 | 14.1 | 296.1 | 12.0 | 3,553.2 | 165.3 | |
| **4** | Pea (kg)** | 17 | 10.8 | 15.9 | 270.3 | 16.5 | 4,460.0 | 207.4 | |
| **5** | Apple (#)* | 23 | 14.6 | 28 | 644 | 26.4 | 17,001.6 | 790.8 | |
| **6** | Potato (kg)** | 39 | 24.8 | 36.1 | 1,407.9 | 3.4 | 4,786.9 | 222.6 | |
| | **Total** | - | - | - | - | - | | | **100.0** |

**Source**: Own HH Survey Data, 2016/17 (**Recall**: * = Seedlings; ** = Seeds; AUC = Average Unit Cost)

**Table 5.9d Amount and Cost of Daily Labor Used by HH of the LC, MC & UC for 2015/16 Season**

| N0 | Sub-catchment | HH | Day Laborer (#) | | AUC and Total Labor Cost (ETB and US$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Average | Total | AUC (ETB) | ETB | US$ | P (%) |
| 1 | LC | 86 | 82 | 7,052 | 21.6 | 152,323.2 | 7,084.8 | 56.8 |
| 2 | MC | 38 | 43 | 1,634 | 23.4 | 38,235.6 | 1,778.4 | 14.3 |
| 3 | UC | 48 | 69 | 3,312 | 23.4 | 77,500.8 | 3,604.7 | 28.9 |
| **4** | **HRC** | **172** | **-** | **-** | **-** | **268,059.6** | **12,467.9** | **100.0** |

**Source**: Own Computation upon HH Survey Data, 2016/17 (AUC = Average Unit Cost)

**Table 5.10a 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 5.10b Area Distribution of HRC upon Categories of Landscape Steepness (Slope Gradient)**

| N0 | Landscape Configuration (Slope) | Area (ha) | P (%) |
|---|---|---|---|
| 1 | Plain, 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: Own Analysis via Arc GIS 9.3 (2017) upon Slope Gradient Classes of FAO (1990)

**Table 5.12 Average Amounts and Costs of Selected HH-Related Variables, HRC in 2015/16**

| N0 | Variable | LC | MC | UC | MC+UC | HRC |
|---|---|---|---|---|---|---|
| 1 | Mean farm (ha/HH) | 0.60 | 0.38 | 0.46 | 0.42 | 0.49 |
| 2 | Average HH size (#/HH) | 5.4 | 5.2 | 5.3 | 5.3 | 5.3 = 5 |
| 3 | Average seed used (kg/HH/Y) | 32.3 | 82.4 | 62.2 | 71.5 | 56.8 |
| 4 | Average of overall labor used (#/HH/Y) | 98 | 141 | 152 | 146.4 | 140.0 |
| 5 | Average (DAP and urea) fertilizer (kg/HH/Y) | 48.6 | 49.5 | 52.9 | 50.9 | 50.0 |
| 6 | Average seedling planted (#/HH/Y) | 53.0 | 31.0 | 51.0 | 42 | 46.0 |
| 7 | Average pair of oxen-power (#/HH/Y) | 16.0 | - | - | - | - |
| 8 | Average cost of DAP fertilizer (ETB/kg) | 15.1 | 15.0 | 15.0 | 15.0 | 15.0 |
| 9 | Average cost of urea fertilizer (ETB/kg) | 12.2 | 12.0 | 12.0 | 12.0 | 12.0 |
| 10 | Mean # of days water pump motor was used/Year | 33.9 | - | - | - | - |
| 11 | Average cost (rent) of water pump motor (ETB/day) | 61.1 | - | - | - | - |
| 12 | Average firewood price (ETB/shoulder) | 46.5 | 47.4 | 47.4 | 47.4 | 47.1 |
| 13 | Average charcoal price (ETB/sack) | 86.2 | 79.0 | 74.5 | 76.8 | 79.9 |

**Source**: Own HH Survey, 2016 – 2017

# Appendix IV: Values of Fuel-Wood Services in HRC (Ch – 6 and Ch - 7)

**Table 6.2c: Weight of a Shoulder of FW and a Sack of Charcoal Measured (by a Balance-beam) from Sample Individuals Who Sell the Products in HRC**

| Product | Date | Sample # (Gender) | Measurement Site | Kg/Shoulder of FW | Average |
|---|---|---|---|---|---|
| Firewood (FW) | 13/02/16 | 1 (female) | LC (Chano) | 21.4 | 20.6 |
| | 13/02/16 | 2 (female) | LC (Chano) | 14.6 | |
| | 16/03/16 | 3 (male) | LC (Shara) | 25.7 | |
| | 07/04/16 | 4 (male) | MC/UC (Dorzie) | 18.5 | 19.2 |
| | 12/04/16 | 5 (female) | MC/UC (Chencha) | 23.2 | |
| | 12/04/16 | 6 (male) | MC/UC (Chencha) | 16.0 | |
| | | **Overall average** | | **19.9** | **19.9** |
| Charcoal | **Date** | **Sample** | **Measurement Site** | **Kg/Sack of Charcoal** | **Average** |
| | 16/03/16 | 1 (male) | LC (Shara) | 27.3 | 23.0 |
| | 19/03/16 | 2 (female) | LC (Chano) | 18.7 | |
| | 12/04/16 | 3 (female) | MC/UC (Chencha) | 20.8 | `22.4 |
| | 12/04/16 | 4 (female) | MC/UC (Chencha) | 24.0 | |
| | | **Overall average** | | **22.7** | **22.7** |

**Source: Own Measurement within 13/02 – 12/04/2016**

Table 6.4a ANOVA on Average Fire-Wood Consumption (FWC) in kg/HH, FW Value (FWV) & FW+Charcoal Value (FW+CV) in US$/HH upon Diff in: **(I)** Gender; **(II)** HH Size (HHS) and **(III)** Crop Produce (CP) among HH of HRC

| N0 | Variable | Measurement | Sum | Df | Mean$^2$ | F | Sig. |
|---|---|---|---|---|---|---|---|
| **I** | FWC (kg/HH/Y) * Gender | Between groups (Combined) | 21.757 | 1 | 21.757 | 22.115 | .000 |
| | | Within groups | 450.580 | 458 | .984 | | |
| | | Total | 472.337 | 459 | | | |
| | FWV (ETB/HH/Y) * Gender | Between groups (Combined) | 20.644 | 1 | 20.644 | 21.733 | .000 |
| | | Within groups | 435.049 | 458 | .950 | | |
| | | Total | 455.693 | 459 | | | |
| | FW+CV (US$/HH/Y) * Gender | Between groups (Combined) | 33.392 | 1 | 33.392 | 29.366 | .000 |
| | | Within groups | 520.791 | 458 | 1.137 | | |
| | | Total | 554.183 | 459 | | | |
| **II** | FWC (kg/HH/Y) * HHS | Between groups (Combined) | 24.547 | 3 | 8.182 | 8.360 | .000 |
| | | Within groups | 445.301 | 455 | .979 | | |
| | | Total | 469.847 | 458 | | | |
| | FWV (US$/HH/Y) * HHS | Between groups (Combined) | 26.670 | 3 | 8.890 | 5.048 | .002 |
| | | Within groups | 801.369 | 455 | 1.761 | | |
| | | Total | 828.039 | 458 | | | |
| | FW+CV (US$/HH) * HHS | Between groups (Combined) | 75.585 | 3 | 25.195 | 13.639 | .000 |
| | | Within groups | 840.524 | 455 | 1.847 | | |
| | | Total | 916.109 | 458 | | | |
| **III** | FWP (kg/HH/Y) * CP | Between groups (Combined) | 93.816 | 20 | 4.691 | 5.440 | .000 |
| | | Within groups | 378.521 | 439 | .862 | | |
| | | Total | 472.337 | 459 | | | |
| | FWV (US$/HH/Y) * CP | Between groups (Combined) | 101.819 | 20 | 5.091 | 3.070 | .000 |
| | | Within groups | 727.874 | 439 | 1.658 | | |
| | | Total | 829.693 | 459 | | | |
| | FW+CV (US$/HH/Y) * CP | Between groups (Combined) | 231.624 | 20 | 11.581 | 7.380 | .000 |
| | | Within groups | 688.941 | 439 | 1.569 | | |
| | | Total | 920.565 | 459 | | | |

**Source**: Computed via SPSS-version 20, 2017

**Table 6.4b**: F & T-Test for Comparison of Average Fire-Wood Consumption (FWC) in kg/HH, FW Value (FWV) & FW+Charcoal Value (FW+CV) in US$/HH b/n HH of the: **(I)** LC vs., MC; **(II)** LC vs., UC **(III)** MC vs., UC of HRC

| N0 | Variable | Assumptio | L. Test for EV | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | F | Sig. | t | df | Sig (2-t) | MD | Std. ED | 95% CI of Diff Lower | Upper |
| **I** | FWC (kg/HH/Year) | EVA | 2.575 | 0.110 | -3.22 | 304 | 0.001 | -.367 | .114 | -.592 | -.143 |
| | | EVNA | | | -3.27 | 298.4 | 0.001 | -.367 | .112 | -.588 | -.147 |
| | FWV (US$/HH/Y) | EVA | 38.214 | 0.000 | -6.51 | 304 | 0.000 | -.894 | .137 | -1.164 | -.624 |
| | | EVNA | | | -6.29 | 240.1 | 0.000 | -.894 | .142 | -1.174 | -.613 |
| | FW+CV ((US$/HH/Y) | EVA | 0.386 | 0.535 | -2.88 | 304 | 0.004 | -.442 | .153 | -.743 | -.141 |
| | | EVNA | | | -2.89 | 287.4 | 0.004 | -.442 | .152 | -.742 | -.142 |
| **II** | FWP (kg/HH/Year) | EVA | .021 | .884 | -1.19 | 325 | .234 | -.137 | .115 | -.364 | .089 |
| | | EVNA | | | -1.19 | 320.7 | .234 | -.137 | .115 | -.364 | .089 |
| | FWV (US$/HH/Y) | EVA | 57.495 | .000 | -3.93 | 325 | .000 | -.553 | .140 | -.829 | -.277 |
| | | EVNA | | | -3.85 | 270.4 | .000 | -.553 | .143 | -.835 | -.271 |
| | FW+CV (US$/HH/Y) | EVA | 7.935 | .005 | -1.30 | 325 | .193 | -.209 | .160 | -.524 | .106 |
| | | EVNA | | | -1.29 | 303.7 | .197 | -.209 | .162 | -.527 | .109 |
| **III** | FWP (kg/HH/Year) | EVA | 3.035 | .083 | 1.975 | 285 | .048 | .230 | .116 | .001 | .459 |
| | | EVNA | | | 1.993 | 284.9 | .047 | .230 | .115 | .003 | .457 |
| | FWV (US$/HH/Y) | EVA | 2.238 | .136 | 2.017 | 285 | .044 | .341 | .169 | .008 | .673 |
| | | EVNA | | | 2.029 | 283.9 | .043 | .341 | .168 | .010 | .671 |
| | FW+CV (US$/HH/Y) | EVA | 5.043 | .025 | 1.358 | 285 | .175 | .233 | .171 | -.105 | .570 |
| | | EVNA | | | 1.376 | 284.8 | .170 | .233 | .169 | -.100 | .566 |

**Source:** OwnComputation via SPSS-version 20, 2017 (L = Levene's, EV = Equality of Variance, EVA = Equality of Variance Assumed, EVNA = Equality of Variance Not Assumed)

**Table 6.4c:** One-Way ANOVA about FW Consumption (FWC), Charcoal Consumption (CC) in kg/HH, FW Value (FWV) and FW+Charcoal Value (FW+CV) in US$/HH upon Difference in "HH Size" among Residents of LC in 2015/16

| Variable | Measurement | Sum of Squares | df | Mean$^2$ | F | Sig. |
|---|---|---|---|---|---|---|
| FWC (kg/HH) | Between groups | 41.871 | 3 | 13.957 | 16.339 | .000 |
| | Within groups | 144.360 | 169 | .854 | | |
| | Total | 186.231 | 172 | | | |
| CC (kg/HH) | Between groups | 1.237 | 3 | .412 | 0.351 | .789 |
| | Within groups | 99.954 | 85 | 1.176 | | |
| | Total | 101.191 | 88 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| FWV (US$/HH) | Between groups | 37.848 | 3 | 12.616 | 16.343 | .000 |
| | Within groups | 130.464 | 169 | .772 | | |
| | Total | 168.312 | 172 | | | |
| FW+CV (US$/HH) | Between groups | 75.641 | 3 | 25.214 | 18.279 | .000 |
| | Within groups | 233.122 | 169 | 1.379 | | |
| | Total | 308.763 | 172 | | | |

**Source**: Own Computation via SPSS-version 20, 2017

**Table 6.4c:** One-Way ANOVA about FW Consumption (FWC), Charcoal Consumption (CC) in kg/HH, FW Value (FWV) and FW+Charcoal Value (FW+CV) in US$/HH upon Difference in "HH Size" among Residents of the MC, UC and the Whole HRC in 2015/16

| Variable | Measurement | Sum of Squares | df | Mean$^2$ | F | Sig. |
|---|---|---|---|---|---|---|
| CC (kg/HH) in HRC (Its value, US$/HH) | Between groups | .632 | 3 | .211 | .185 (.156) | .906 (.926) |
| | Within groups | 141.235 | 124 | 1.139 | | |
| | Total | 141.867 | 127 | | | |
| FW use in HRC (Its value, US$/HH) | Between groups | 24.547 | 3 | 8.182 | 8.360 (7.714) | .000 (.000) |
| | Within groups | 445.301 | 455 | .979 | | |
| | Total | 469.847 | 458 | | | |
| FWC (kg/HH) in MC (Its value, US$/HH) | Between groups | 1.747 | 3 | .582 | .690 | .560 |
| | Within groups | 108.930 | 129 | .844 | | |
| | Total | 110.677 | 132 | | | |
| FWC (kg/HH) in UC (Its value, US$/HH) | Between groups | 11.195 | 3 | 3.732 | 3.634 | .014 |
| | Within groups | 154.032 | 150 | 1.027 | | |
| | Total | 165.227 | 153 | | | |

**Source**: Own Computation via SPSS-version 20, 2017

**Table 6.4d: ANOVA about Charcoal Use & Its Value Based on Difference in "HH Size" among Residents of: (I) the LC and (II) the Whole HRC in 2015/16**

| N0 | Variable | Measurement | Sum of Squares | Df | Mean$^2$ | F | Sig. |
|---|---|---|---|---|---|---|---|
| I | Charcoal use (kg/HH/Year) | Between groups | 1.237 | 3 | .412 | .351 | .789 |
| | | Within groups | 99.954 | 85 | 1.176 | | |
| | | Total | 101.191 | 88 | | | |
| | Charcoal value (US$/HH/Year) | Between groups | 1.237 | 3 | .412 | .351 | .789 |
| | | Within groups | 99.954 | 85 | 1.176 | | |
| | | Total | 101.191 | 88 | | | |
| II | Charcoal use (kg/HH/Year) | Between groups | .632 | 3 | .211 | .185 | .906 |
| | | Within groups | 141.235 | 124 | 1.139 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Total | 141.867 | 127 | | | |
| Charcoal value (US$/HH/Year) | Between groups | .458 | 3 | .153 | .156 | .926 |
| | Within groups | 121.417 | 124 | .979 | | |
| | Total | 121.875 | 127 | | | |

**Source**: Own Computation via SPSS-version 20, 2017

**Table 6.4e: Independent Samples Test for Comparison of Average Charcoal Consumption (ACC) in kg/HH/Yearand Average Charcoal Value (ACV) in US$/HH/Year between the LC vs., MC+UC of HRC**

| | | Levene's Test for EV | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | F | Sig. | t | df | Sig. (2-t) | MD | Std. ED | 95% CI of Diff | |
| | | | | | | | | | Lower | Upper |
| MCC | EVA | .135 | .714 | -.052 | 127 | .959 | -.010 | .201 | -.409 | .387 |
| | EVNA | | | -.053 | 78.6 | .958 | -.010 | .198 | -.404 | .383 |
| MCV | EVA | 17.602 | .000 | 1.706 | 127 | .090 | .315 | .184 | -.050 | .679 |
| | EVNA | | | 2.012 | 112.7 | .047 | .315 | .156 | .005 | .624 |

**Source**: Computed via SPSS-version 20, 2017 (**EV** = Equality of Variance)

Table 6.4f: ANOVA on Level of Consumption & Value of FW & Charcoal upon Difference in: **(I)** Level of Income from Crop harvest; and **(II)** HH Size among Residents of HRC in 2015/16

| N | Variable | Measure | Sum of Squares | df | Mean$^2$ | F | Sig. |
|---|---|---|---|---|---|---|---|
| I | FW consumption (kg/HH/Year) | Between groups | 406.611 | 5 | 81.322 | 561.731 | .000 |
| | | Within groups | 65.726 | 454 | .145 | | |
| | | Total | 472.337 | 459 | | | |
| | FW & charcoal value, US$/HH/Y | Between groups | 126.164 | 14 | 9.012 | 9.831 | .000 |
| | | Within groups | 407.931 | 445 | .917 | | |
| | | Total | 534.096 | 459 | | | |
| II | FW consumption (kg/HH/Year) | Between groups | 24.547 | 3 | 8.182 | 8.360 | .000 |
| | | Within groups | 445.301 | 455 | .979 | | |
| | | Total | 469.847 | 458 | | | |
| | FW & charcoal value, US$/HH/Y | Between groups | 53.129 | 3 | 17.710 | 16.950 | .000 |
| | | Within groups | 475.381 | 455 | 1.045 | | |
| | | Total | 528.510 | 458 | | | |

**Source**: Computed via SPSS-version 20, 2017 [FW = Fire-Wood]

**Table 6.5a: Energy Source for Domestic (Home) Consumption by HH of HRC & Its Sub-catchments in 2015/16**

| N0 | Energy Source | LC | | MC | | UC | | HRC | |
|---|---|---|---|---|---|---|---|---|---|
| | | HH | P (%) | HH | P (%) | HH | P (%) | HH | P (%) |
| **1** | Firewood | 173 | 99.4 | 133 | 99.3 | 157 | 100.0 | 463 | 99.6 |
| **2** | Charcoal | 89 | 51.1 | 10 | 7.5 | 30 | 19.1 | 129 | 27.7 |
| **3** | Gas (naphtha) | 62 | 35.6 | 106 | 79.1 | 117 | 74.5 | 285 | 61.3 |
| **4** | Animal dung | 0 | 0.0 | 6 | 4.5 | 16 | 10.2 | 22 | 4.7 |
| **5** | Crop residue | 6 | 3.5 | 3 | 2.2 | 11 | 7.0 | 20 | 4.3 |
| **6** | Electric (LC) and/or solar cell power | 92 | 52.9 | 27 | 20.1 | 19 | 12.1 | 138 | 29.7 |
| | **Total** | **174** | **100.0** | **134** | **100.0** | **157** | **100.0** | **465** | **100.0** |

**Source**: Own Field Survey, 2016/17 [**Recall**: (i) solar cell power is used in LC, MC & UC; but, electric power was used in LC only; (ii) the data in the table above are results of multiple response options]

**Table 6.5b Correlation between FW, Charcoal, Crop Harvest & Crop Value for HH of HRC (2015/16)**

| | | FWC (S/HH) | CC (kg) | CH (Q) | CV (US$) | HH Size |
|---|---|---|---|---|---|---|
| **FW Consumption (FWC) (kg/HH/Year)** | Pearson's 'r' | 1 | | | | |
| | Sig. (2-tail) | | | | | |
| | N | 460 | | | | |
| **Charcoal Consumption (CC)_kg/HH/Year** | Pearson's 'r' | -.117 | 1 | | | |
| | Sig. (2-tail) | .185 | | | | |
| | N | 129 | 129 | | | |
| **Crop Harvest (CH) (Quintal/HH/Year)** | Pearson's 'r' | .368** | -.020 | 1 | | |
| | Sig. (2-tail) | .000 | .824 | | | |
| | N | 460 | 129 | 465 | | |
| **Crop Value (CV) (US$/HH/Year)** | Pearson's 'r' | .364** | .015 | .950** | 1 | |
| | Sig. (2-tail) | .000 | .863 | .000 | | |
| | N | 460 | 129 | 465 | 465 | |
| **HH size (#)** | Pearson's 'r' | .215** | .001 | .376** | .347** | 1 |
| | Sig. (2-tail) | .000 | .992 | .000 | .000 | |
| | N | 459 | 128 | 464 | 464 | 464 |

**. Correlation is significant at the 0.01 level (2-tailed). (**Source:** Own Computation via SPSS-V-20, 2017)

**Table 6.7 ANOVA about Firewood and Charcoal Value (US$/HH/Year) upon Difference in "HH Size" among Residents of the LC, MC, UC and the Whole HRC in 2015/16**

| N0 | Area | Measurement | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|
| 1 | LC | Between groups | 131.599 | 3 | 43.866 | 19.866 | .000 |
| | | Within groups | 373.164 | 169 | 2.208 | | |
| | | Total | 504.763 | 172 | | | |
| 2 | MC | Between groups | 10.188 | 3 | 3.396 | 1.499 | .218 |
| | | Within groups | 292.173 | 129 | 2.265 | | |
| | | Total | 302.361 | 132 | | | |
| 3 | UC | Between groups | 51.564 | 3 | 17.188 | 6.440 | .000 |
| | | Within groups | 400.339 | 150 | 2.669 | | |
| | | Total | 451.903 | 153 | | | |
| 4 | HRC | Between groups | 84.490 | 3 | 28.163 | 11.010 | .000 |
| | | Within groups | 1163.841 | 455 | 2.558 | | |
| | | Total | 1248.331 | 458 | | | |

**Source**: Own Computation via SPSS-version 20, 2017

**Table 6.8a: Area Distribution (in %) Based on LULC Classes of HRC**

| N0 | LULC Classes | **1967** | | **1976** | **1985** | **1995** | **2003** | **2015** | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Area (ha)** | **%** | **(%)** | **(%)** | **(%)** | **(%)** | **Area (ha)** | **P (%)** |
| 1 | Forest | 2835.4 | 12.1 | 5.1 | 4.1 | 4.3 | 3.8 | 609.2 | 2.6 |
| 2 | Riverine vegetation | 2530.7 | 10.8 | 6.5 | 7.4 | 5.5 | 3.5 | 1124.8 | 4.8 |
| 3 | Cropland & settle | 5577.0 | 23.8 | 40.0 | 57.3 | 50.2 | 56.1 | 14809.5 | 63.2 |
| 4 | Bush/shrub | 4077.3 | 17.4 | 24.8 | 16.8 | 20.6 | 12.4 | 2905.6 | 12.4 |
| 5 | Woodland | 6842.3 | 29.2 | 13.4 | 6.2 | 4.0 | 10.2 | 2647.9 | 11.3 |
| 6 | Grassland | 1570.0 | 6.7 | 10.2 | 8.2 | 15.4 | 14.0 | 1335.7 | 5.7 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Total** | **23432.7** | **100** | **100** | **100** | **100** | **100** | **23432.7** | **100** |

Source: Computed via Arc-GIS 9.3

**Table 6.8b Ecosystem Service Value (ESV) of Hare in 1967, 1976, 1985, 1995, 2003 & 2015**

| LUC Class | Annual ESV in US$ ('000') | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1967** | | **1976** | | **1985** | | **1995** | | **2003** | | **2015** | |
| | ESV | P (%) | ESV | P (%) | ESV | P (%) | ESV | P (%) | ESV | P (%) | ESV | P (%) |
| Forest | 2,758 | 30.3 | 1,146 | 18.1 | 925 | 16.4 | 975 | 17.6 | 864 | 17.2 | 586 | 12.1 |
| RV | 2,457 | 27.0 | 1,470 | 23.2 | 1,683 | 29.8 | 1,240 | 22.4 | 793 | 15.8 | 1,100 | 22.8 |
| CS | 512 | 5.6 | 862 | 13.6 | 1,236 | 21.9 | 1,082 | 19.5 | 1,208 | 24.1 | 1,362 | 28.2 |
| B/S | 945 | 10.4 | 1,350 | 21.3 | 914 | 16.2 | 1,121 | 20.2 | 674 | 13.4 | 674 | 14.0 |
| W | 2,069 | 22.7 | 948 | 15.0 | 438 | 7.8 | 286 | 5.2 | 725 | 14.4 | 799 | 16.5 |
| G | 362 | 4.0 | 554 | 8.8 | 443 | 7.9 | 834 | 15.1 | 758 | 15.1 | 308 | 6.4 |
| Total | **9,103** | **100** | **6,330** | **100** | **5,639** | **100** | **5,538** | **100** | **5022** | **100** | **4,829** | **100** |

**Source**: Own Computation, 2017

Table 6.9 ANOVA about Level of Firewood (FW) Consumption and Its Value, and Amount of FW and Charcoal (FWC) Value among Residents of HRC in 2015/16

| Variable | Measurement | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| FW use | Between groups | 461.170 | 437 | 1.055 | 2.079 | .021 |
| | Within groups | 11.167 | 22 | .508 | | |
| | Total | 472.337 | 459 | | | |
| FW value | Between groups | 461.170 | 437 | 1.055 | 2.079 | .021 |
| | Within groups | 11.167 | 22 | .508 | | |
| | Total | 472.337 | 459 | | | |
| FWC value | Between groups | 526.596 | 437 | 1.205 | 3.535 | .000 |
| | Within groups | 7.500 | 22 | .341 | | |

| | | | |
|---|---|---|---|
| | Total | 534.096 | 459 |

**Source**: Own Computation via SPSS-version 20, 2017

**Table 6.10: Average Gross Value (GV), Net Economic Value (NEV), Per Capita GV and Per Capita NEV of Crop Harvest and Fuel Product (Firewood & Charcoal) Services for HH of HRC in 2015/16**

| Service | N0 | Measurement | LC | MC | UC | MC+UC | HRC |
|---|---|---|---|---|---|---|---|
| Crop harvest | 1 | Average gross value (US$) | 971.4 | 499.3 | 556.5 | 530.2 | 695.3 |
| | 2 | Average NEV (US$) | 893.1 | 445.0 | 496.6 | 472.8 | 630.1 |
| | 3 | Per capita gross value (US$) | 194.3 | 99.9 | 111.3 | 106.1 | 139.1 |
| | 4 | Per capita NEV(US$) | 178.6 | 89.0 | 99.3 | 94.6 | 126.0 |
| Fuel-wood products | 5 | Average gross value (US$) | 180.5 | 188.5 | 178.2 | 183.0 | 182.0 |
| | 6 | Average NEV (US$) | 180.5 | 188.5 | 178.2 | 183.0 | 182.0 |
| | 7 | Per capita gross value (US$) | 36.1 | 37.7 | 35.6 | 36.6 | 36.4 |
| | 8 | Per capita NEV (US$) | 36.1 | 37.7 | 35.6 | 36.6 | 36.4 |
| Crop and fuel-wood | 9 | Average gross value (US$) | 1,151.9 | 687.8 | 734.7 | 713.2 | 877.3 |
| | 10 | Average NEV (US$) | 1,073.6 | 633.5 | 674.8 | 655.8 | 812.1 |
| | 11 | Per capita gross value (US$) | 230.4 | 137.6 | 146.9 | 142.7 | 175.5 |
| | 12 | Per capita NEV (US$) | 214.7 | 126.7 | 134.9 | 131.2 | 162.4 |
| | 13 | HH size | 5 (5.4) | 5 (5.2) | 5 (5.1) | 5 (5.2) | 5 (5.3) |
| | 14 | Sample HH | 174 | 134 | 157 | 291 | 465 |

**Source: Own Computation, 2017/18**

Table 6.11a: Important Tree Species of Forest, Woodland and/or Bush/Shrub Resources of HRC Used for Generating Fuel-Wood and Timber Products by HH of the Catchment

| N0 | Sub-catchment | N0 | Names of Trees | |
|---|---|---|---|---|
| | | | English/Amharic | Scientific |
| I | Lower Catchment | 1 | Acacia | *Acacia albida* |
| | | 2 | Bitter-leaf (*grawa*) | *Vernonia amygdalina* |
| | | 3 | Desert-date (*bedeno*) | *Balanites aegyptiaca* |
| | | 4 | Flamboyant (*diredawa-zaf*) | *Delonix regia* |
| | | 5 | Cabbage tree (*shiferaw)* | *Moringa oleifera* |
| | | 6 | Eucalyptus (*key-bahir-zaf*) | *Eucalyptus camaldulensis* |
| | | 7 | *Kontir* | *Acacia senegal* |
| | | 8 | Avocado tree | *Persea Americana* |

| | | | | |
|---|---|---|---|---|
| | | 9 | Mango tree | *Mangifera indica* |
| | | 10 | Lemon tree | *Citrus aurantifolia* |
| | | 11 | Woybeta | - |
| | | 12 | Sockie tree | - |

Source: Own Field Survey (2016 – 2017)

Table 6.11b: Important Tree Species of Forest, Woodland and/or Bush/Shrub Resources of HRC Used for Generating Fuel-Wood and Timber Products by HH of the Catchment

| **N0** | **Sub-catchment** | **N0** | **Names of Trees** | |
|---|---|---|---|---|
| | | | **English/Amharic** | **Scientific** |
| II | Middle and Upper Catchments | 1 | Broad-leaved croton (*bisana*) | *Croton macrostachyus* |
| | | 2 | Flat-top acacia | *Acacia abyssinica* |
| | | 3 | Olive (*woira*) | *Cuspidata olea africana* |
| | | 4 | *Tid* | *Juniperus procera* |
| | | 5 | Mexican cypress (*yeferenji-tid*) | *Cupressus lusitanica* |
| | | 6 | Hop-bush *(kitkita)* | *Dodonaea viscosa* |
| | | 7 | Bitter-leaf (*grawa*) | *Vernonia amygdalina* |
| | | 8 | *Embus* | *Allophylus abyssinicus* |
| | | 9 | *Koshim* | *Dovyalis abyssinica* |
| | | 10 | *Kosso* | *Hagenia abyssinica* |
| | | 11 | Grevillea | *Grevillea robusta* |
| | | 12 | Eucalyptus (*nech* or *shito bahir-zaf*) | *Eucalyptus citriodora* |
| | | 13 | *Gumero* | *Capparis tomentosa* |
| | | 14 | Peach*(kock)* | *Prunus persica* |
| | | 15 | Mountain bamboo | *Arundinaria alpine* |
| | | 16 | Reed-grass (*shembeko*) | *Arundo donax* |
| | | 17 | Apple tree | *Malus domestica* |
| | | 18 | Manna (ribbon) gum | *Eucalyptus viminalis* |

Source: Own Field Survey (2016 – 2017)

**Table 7.1c Comparison of Average Income from Crop and Fuel-Wood Products between HH of the: (I) LC vs., MC, (II) LC vs., UC, and (III) MC vs., UC of Hare in 2015/16**

| N0 | Assumption | Levene's Test for EV | | T – Test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | F | Sig | t | df | Sig (2-t) | MD | Std. ED | 99% CI of Diff | |
| | | | | | | | | | Lower | Upper |
| I | EVA | 44.34 | 0.000 | 6.39 | 306 | 0.000 | 1.034 | 0.16 | 0.61 | 1.45 |
| | EVNA | | | 6.97 | 253.3 | 0.000 | 1.034 | 0.15 | 0.65 | 1.42 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| II | EVA | 23.47 | 0.000 | 5.79 | 329 | 0.000 | 0.93 | 0.16 | 0.51 | 1.35 |
| | EVNA | | | 5.93 | 290.8 | 0.000 | 0.93 | 0.16 | 0.52 | 1.34 |
| III | EVA | 6.84 | 0.009 | -0.93 | 289 | 0.354 | -0.10 | 0.11 | -0.39 | 0.19 |
| | EVNA | | | -0.95 | 283.1 | 0.342 | -0.10 | 0.11 | -0.39 | 0.18 |

**Source:** Own Computation (2018) via SPSS [**Recall**: EV = Equality of Variance; EVA = Equal Variance is Assumed; EVNA = Equal Variance Not Assumed; MD = Mean Difference; ED = Error of Difference; CI = Confidence Interval;

**Table 7.1a**ANOVA of Average Income from Crop, Fire-Wood and Charcoal (CFWC) Products upon Difference in Gender, HH-Size and Farm-Size of HH in the LC, MC and UC of Hare, 2015/16

| Area | Variable/Factor | Measurement | Sum of Squares | df | Mean$^2$ | F | Sig |
|---|---|---|---|---|---|---|---|
| LC | CFWC income*Gender (Mean Comparison) | Between groups | 13.385 | 1 | 13.385 | 4.506 | 0.035 |
| | | Within groups | 510.919 | 172 | 2.970 | | |
| | | Total | 524.305 | 173 | | | |
| | CFWC income*HH-size (One-way ANOVA) | Between groups | 259.984 | 3 | 86.661 | 55.737 | 0.000 |
| | | Within groups | 264.321 | 170 | 1.555 | | |
| | | Total | 524.305 | 173 | | | |
| | CFWC income*Farm-size (One-way ANOVA) | Between groups | 387.016 | 9 | 43.002 | 51.369 | 0.000 |
| | | Within groups | 137.288 | 164 | 0.837 | | |
| | | Total | 524.305 | 173 | | | |
| MC | CFWC income*Gender (Mean Comparison) | Between groups | 9.776 | 1 | 9.776 | 17.931 | 0.000 |
| | | Within groups | 71.963 | 132 | 0.545 | | |
| | | Total | 81.739 | 133 | | | |
| | CFWC income*HH size (One-way ANOVA) | Between groups | 12.170 | 3 | 4.057 | 7.580 | 0.000 |
| | | Within groups | 69.569 | 130 | 0.535 | | |
| | | Total | 81.739 | 133 | | | |
| | CFWC income*Farm-size (One-way ANOVA) | Between groups | 33.679 | 5 | 6.736 | 17.940 | 0.000 |
| | | Within groups | 48.060 | 128 | 0.375 | | |
| | | Total | 81.739 | 133 | | | |
| UC | CFWC income*Gender (Mean Comparison) | Between groups | 7.978 | 1 | 7.978 | 7.317 | 0.008 |
| | | Within groups | 169.015 | 155 | 1.090 | | |
| | | Total | 176.994 | 156 | | | |
| | CFWC income*HH size (One-way ANOVA) | Between groups | 44.491 | 3 | 14.830 | 17.124 | 0.000 |
| | | Within groups | 132.503 | 153 | 0.866 | | |
| | | Total | 176.994 | 156 | | | |
| | CFWC income*Farm-size (One-way ANOVA) | Between groups | 127.218 | 7 | 18.174 | 54.403 | 0.000 |
| | | Within groups | 49.775 | 149 | 0.334 | | |
| | | Total | 176.994 | 156 | | | |

**Source**: Own Computation (2018) upon Own Survey Data (2016-2017) (Significance at 95%)

**Table 7.1bANOVA of Average Income (ETB/US$) from Crop, Fire-Wood and Charcoal (CFWC) Services upon Difference in Gender, HH-Size and Farm-Size of HH of HRC in 2015/16**

| N0 | Variable/Factor | Measurement | Sum of Squares | Df | Mean$^2$ | F | Sig |
|---|---|---|---|---|---|---|---|
| I | CFWC earning*gender | Between groups | 31.624 | 1 | 31.624 | 17.098 | 0.000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | (Mean comparison) | Within groups | 856.341 | 463 | 1.850 | | |
| | | Total | 887.966 | 464 | | | |
| II | CFWC earning*HH-size (One-way ANOVA) | Between groups | 113.267 | 3 | 37.756 | 22.817 | 0.000 |
| | | Within groups | 761.162 | 460 | 1.655 | | |
| | | Total | 874.429 | 463 | | | |
| III | CFWC earning*farm-size (One-way ANOVA) | Between groups | 587.643 | 9 | 65.294 | 98.922 | 0.000 |
| | | Within groups | 300.323 | 455 | .660 | | |
| | | Total | 887.966 | 464 | | | |

**Source**: Own Computation (2018) upon Own Survey Data (2016-2017) (Significance at 99%)

## Appendix V: Summarized Data and Figures about HRC

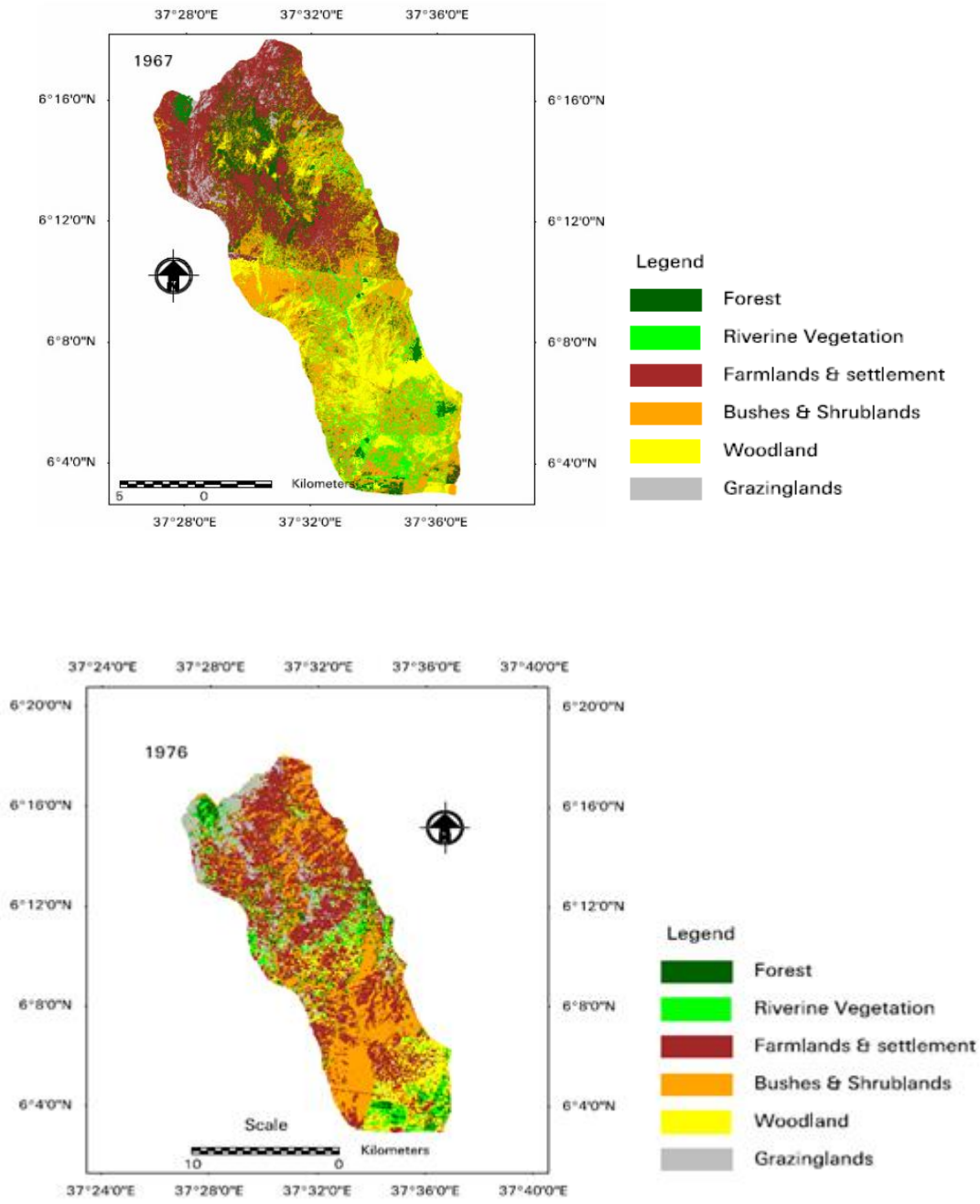


**Figure 3.5a** LULC Classes of HRC in: (i)1967 (top) and (ii) 1976(bottom) **[Source**: Analysis via ERDAS 3.8 and Arc GIS 9.3]

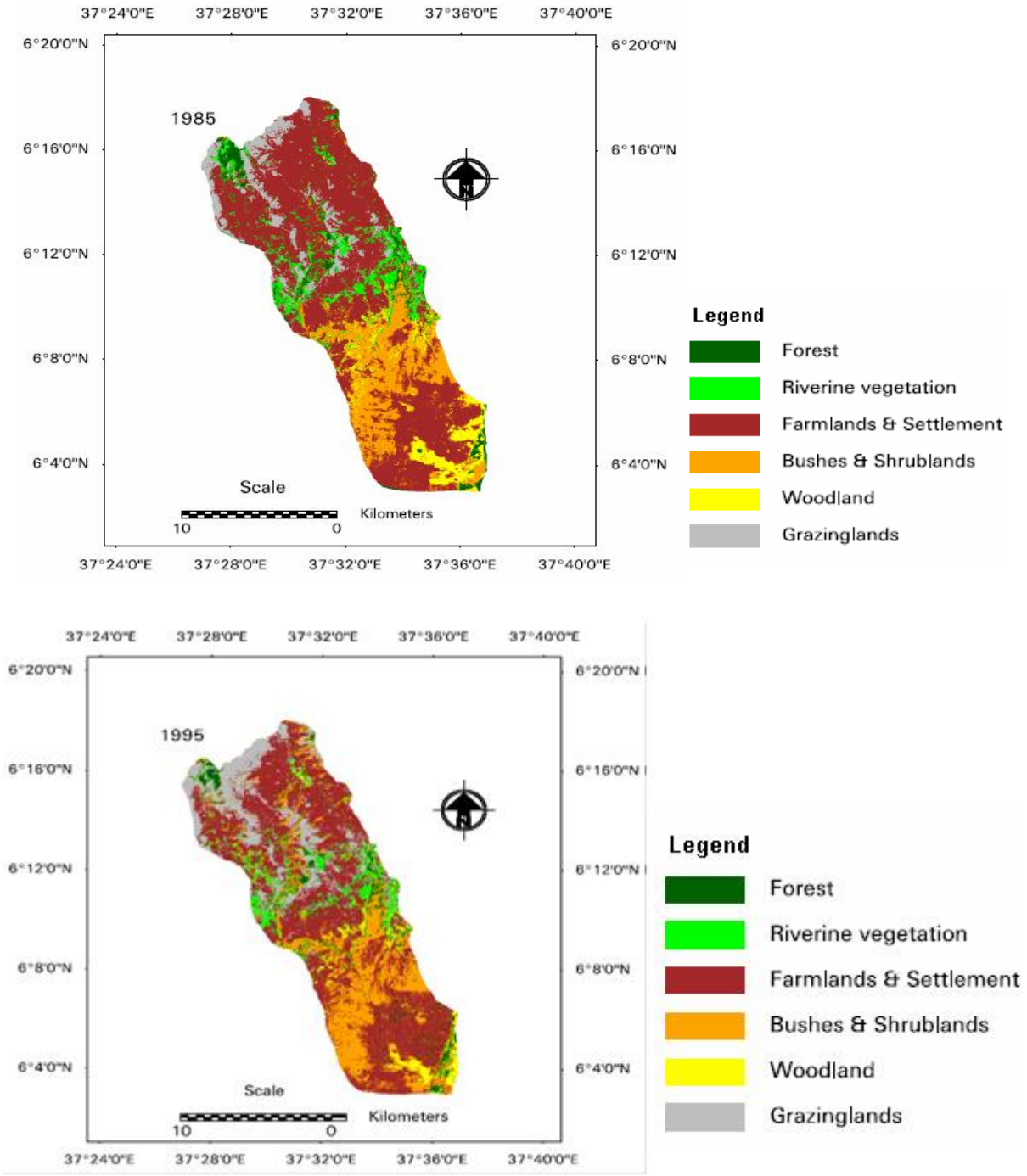


**Figure 3.5b** LULC Classes of HRC in: **(i)** 1985 (top) and, **(ii)** 1995 (bottom) **[Source**: Analysis via ERDAS 3.8 and Arc GIS 9.3]

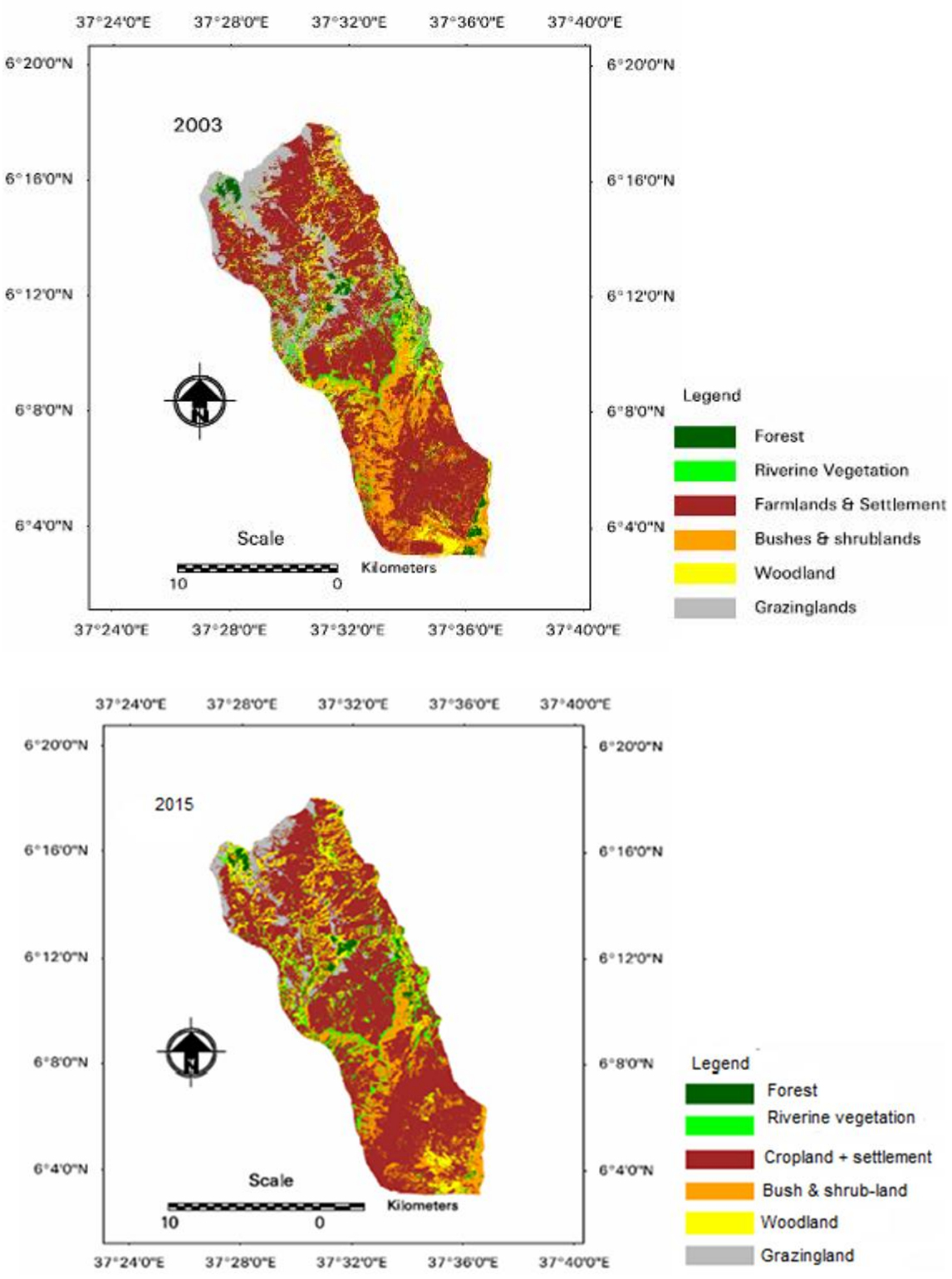


**Figure 3.5c** LULC Classes of HRC in: **(i)** 2003 (top) and, **(ii)** 2015 (bottom) **[Source**: Analysis via ERDAS 3.8 and Arc GIS 9.3]

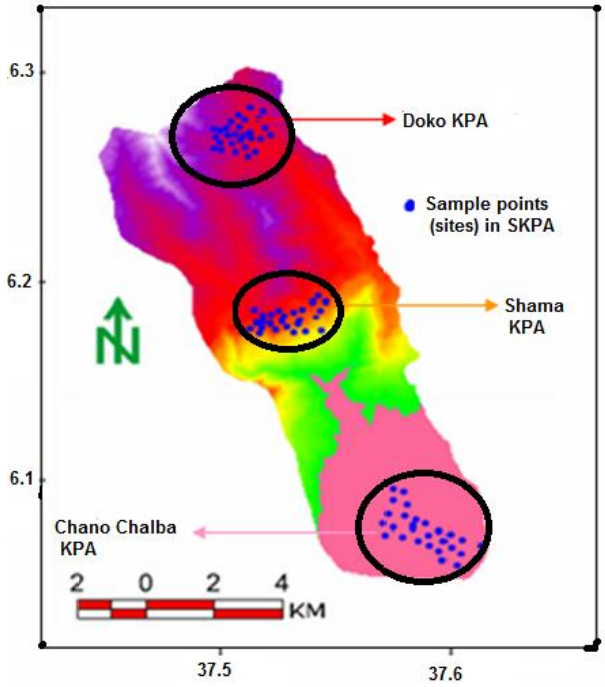


**Figure 3.6** Sample KPA of HRC Used for HH & Environmental Survey **(Source:** Illustrated upon Arc GIS 9.3)**Recall**: SKPA is Sample Kebele Peasant Administration

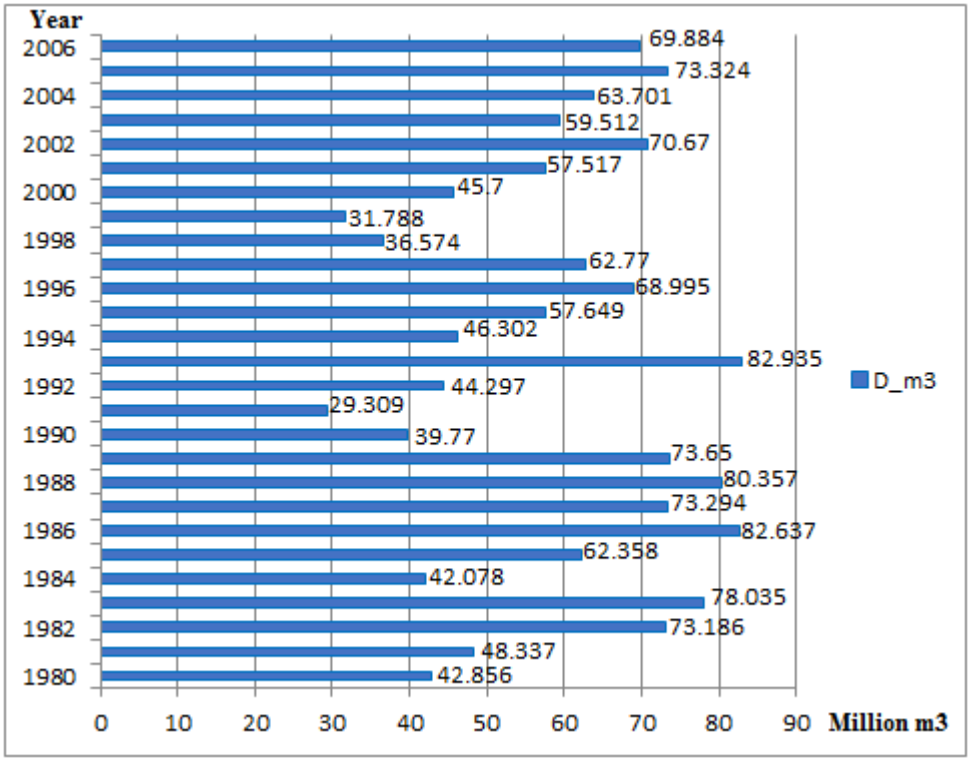


**Figure 6.11: Annual Water Discharge (D) of Hare River (in '000,000' $m^3$) within 1980 – 2006. Source: Own Design via Excel, 2017 Based on Data Recorded by GTSO/GTZ (2008)**

Figure 6.12 **(a)** Forest (the left), **(b)** Riverine vegetation (the middle) and **(c)** Cropland and settlement (the right) photo above (**Source:** Own taken picture/photo during field survey, 2016 – 2017)

Figure 6.13 **(a)** Bush/shrub (the left), **(b)** Woodland (the middle) and **(c)** Grazing-land (the right) photo above (**Source:** Own taken picture/photo during field survey, 2016 – 2017)