Global Scientific JOURNALS

GSJ: Volume 7, Issue 9, September 2019, Online: ISSN 2320-9186
www.globalscientificjournal.com

AGRO-ECOSYSTEM RESILIENCE TO CLIMATE CHANGE IN THE KOGA WATERSHED OF THE BLUE NILE BASIN, ETHIOPIA

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KeyWords

Blue Nile Basin, Koga, Watershed, climate change, agro-ecosystem, resilience, Ethiopia.

ABSTRACT

Enhancing the resilience of social-ecological systems as a critical response option to climate change was cited in the literature, and assessing the resilience of agro-ecosystems to climate change in the Koga Watershed of the Blue Nile Basin is the focus of this study. The study compared the resilience of two distinct farming systems (irrigation supplemented downstream and rain-fed upstream) created due to the introduction of the Koga irrigation scheme. Household level data were collected on indicators of agro-ecosystem resilience determined by the results of three focus group discussions and a literature review. Data analysis involved descriptive statistics, independent samples 't' test and multiple regression. The results of the study showed significant differences in many of the agro-ecosystem resilience indicators and socio-economic variables between the upstream and downstream Koga Watershed. The study also showed that farming experience by far most strongly determined agro-ecosystem resilience to climate change, followed by age of household head and soil fertility. Overall, the irrigation supplemented farming systems of the downstream tended to be more resilient than rain-fed upstream farming systems. Therefore, the study concluded that irrigation schemes not only enhance the adaptive capacity of individual farmers but also the farming system as a whole. Thus, while considering possible measures to build the agro-ecosystems of the watershed as a whole, it should be a priority for stakeholders to enhance the resilience of agro-ecosystems to climate change in the upstream Koga Watershed.

1. INTRODUCTION

Given climate change is a reality and that it is already affecting ecological and human systems in unprecedented and often unpredictable ways [22-25], participatory research that allows stakeholders to participate could help to bring the theoretical concepts of climate change impacts and the resilience of social-ecological systems to a concrete local level.

Specific to climate change, social-ecological resilience is 'the resilience of a system or part of a system to climate-related shocks and stresses, i.e., the ability to survive, recover from, and even thrive in changing climatic conditions, and in the process, maintain essential functions, identities and structures'[26] (p.134). Agro-ecosystems, which are ecological and socioeconomic systems comprising domesticated plants and/or animals and the people who manage them [27], are typical examples of linked social-ecological systems which are highly vulnerable to climate impacts. Given specific biophysical and community dynamics, some households and communities of the Koga watershed and the ecosystems on which they depend may be less resilient to the effects of climate change than others. This study seeks to understand the local effects and resiliencies of these social-ecological systems to climate change, and contribute to the incorporation of scientific knowledge into smaller scale adaptation planning in order to enhance agro-ecosystem resilience in the watershed. Subsystems within a larger system follow different trajectories, or follow the same trajectory at different speeds [28]. Therefore, it is assumed that trends in the biophysical and socio-economic characteristics vary at the upstream and downstream geographical settings and consequently, the agro-ecosystem resilience status of these two distinct units of the watershed are also varied.

The objectives of this paper are, therefore. to (1) compare indicators for agro-ecosystem resilience in downstream and upstream farm households of Koga Watershed; (2) compare the overall resilience of agro-ecosystems to climate change between the downstream and upstream units; (3) make a comparison of household-level socio-economic variables that potentially influence agro-ecosystem resilience between downstream and upstream communities; and (4) explore the socio-economic determinants of agro-ecosystem resilience to climate change.

2. MATERIAL AND METHODS

2.1. Description of the Study Area

The Koga River which is about 46 kms long is a tributary of the Gilgel Abay River in the headwaters of the Blue Nile Basin. The source of the river is the Wezem Mountain located at an altitude of about 3000 meters amsl. The Koga Watershed lies between 11°7' to 11°28' north latitude and 37°3' to 37°15' east longitude (Figure 1). The watershed has a total area of about 259 km^2. It is located in Mecha Woreda (District) of the Amhara National Regional State where seventeen rural 'Kebeles' are found within the watershed. The watershed is narrower and steeper in the upstream and wider and gentler in the downstream part. The climate in the study area, as in many parts of Ethiopia, is mainly controlled by the seasonal migration of the Inter Topical Convergence Zone (ITCZ) (NMSA, 2001). Accordingly, it has distinct rainy and dry seasons. The annual climate cycle is characterized by a prolonged wet season extending from May through October, a dry season with cooler conditions from November through February, and hot and dry conditions in March and April. The average annual rainfall calculated using data from Bahir Dar meteorological station for the period of 33 years (1980 – 2012) is 1424.5 mm. The rains usually begin during May and peak in July and August; and continue to decline until the onset of the new wet season. Traditional subsistence farming on small individual holdings and customary grazing on communal lands is the dominant human activity in the watershed (Mekonen and Kebede, 2011; Yeshaneh, 2013).
The average farm size of individual farmers is about 2.1 ha where the farms are situated within walking distance and gardens are cultivated nearby (Eguavoe and Tesfai, 2012). The ecosystem services provided by farming in the Koga Watershed include production of cereals for food and livestock production. The farmers grow a wide variety of cereal crops and raise some livestock. Cereals predominantly produced in the rain-fed farms include teff, maize, barley and millet; whereas pulses, oilseeds and some legumes are produced in a small percentage of the irrigated cultivated area of the Koga watershed (Yeshaneh, 2013). Cattle, goats and sheep are common animals raised in the watershed. Farm households also commonly keep chickens. Most of the farmers' produce goes to family consumption and they market a small proportion of cereal crops, livestock and dairy products locally.

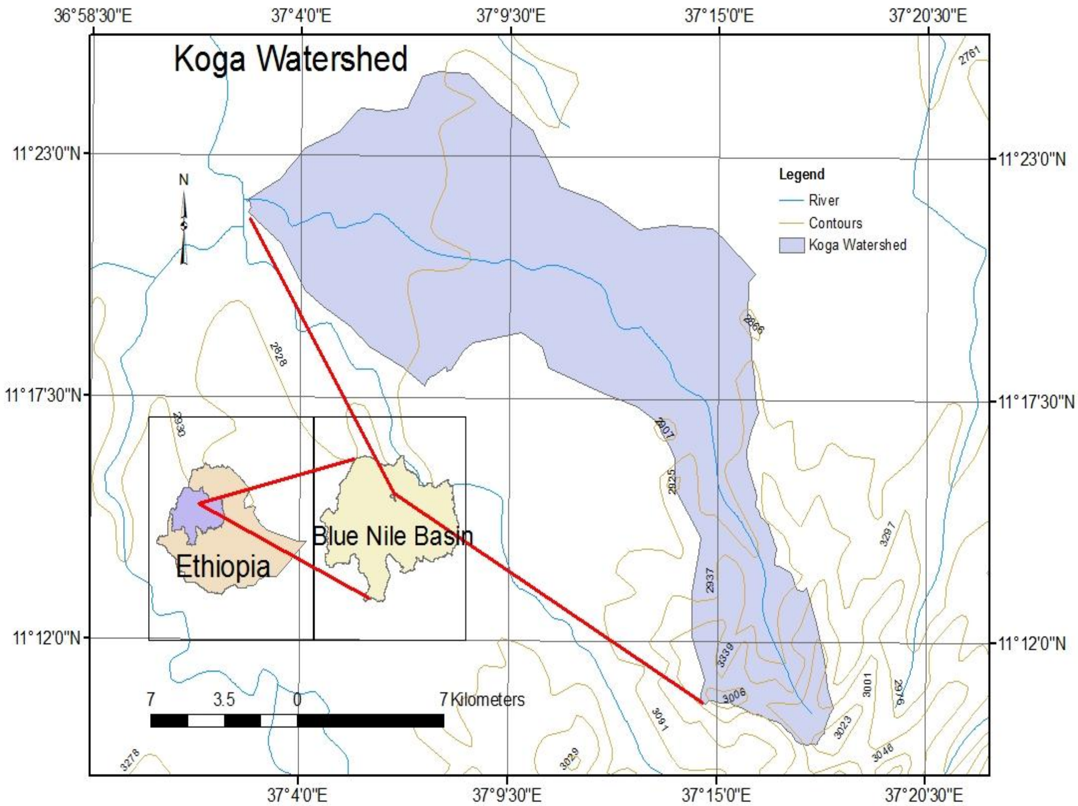

Figure 1. Map of the Study Area

2.2. Indicators of Agro-ecosystem Resilience to climate change

Climate change resilience in itself is difficult to define and is a product of a potentially vast range of aspects covering all human-environment systems. For Carpenter et al., [29], resilience is a conceptual theoretical foundation and it is practically difficult to measure it. However, social-ecological system resilience to disturbances can be assessed through indicators that measure the ability of a system to absorb shocks and retain is basic function; self-organize; and learning and adaptation in the face of disturbances [30]. Agro-ecosystems exemplify all the complexity a social-ecological system can possibly have, making it nearly impossible to account for every factor that contributes to resilience [31]. So, they suggested that developing sets of indicators as a more useful approach to assessing resilience than trying to measure resilience itself.

Indicators are variables that provide aggregated information on certain phenomena [32]. In assessing states and trends in human-environmental systems like agro-ecosystems, Heink and Kowarik [33] defined indicators as components or measures of environmentally relevant phenomena used to depict or evaluate environmental conditions or changes or to set environmental goals.

In order to assess the resilience of agro-ecosystems to climate change, indicators must represent the three dimensions of resilience namely: buffer capacity, self-organization and the capacity to learn and adapt. Cabell and Oelesfe [34] compiled 13 behavior-based indicators directly concerned with agro-ecosystems and related to the three dimensions of resilience. The indicators are: socially self-organized; ecologically self-regulated; appropriately connected; high degree of functional and response diversity; optimally redundant; high degree of spatial and temporal heterogeneity; carefully exposed to disturbance; responsibly coupled with local natural capital; reflected and shared learning; globally autonomous and locally interdependent; honors legacy while investing in the future; builds human capital; and reasonably profitable. According to Cabell and Oelesfe [34], the absence of these behaviors signals vulnerability in the agro-ecosystem and the presence of these indicators imply that the system is resilient. Reed, Dougill, Taylor [35] argue that contextually-relevant information and locally-identified indicators provide a practical way to monitor progress and also increase the potential of generating contextually relevant solutions that can not only increase resilience but also empower farmers in the process. In this regard, eight indicators were chosen by their contextual relevance and the possibility of deriving them from questionnaire results. These include diversity (both functional and response), economic viability and self-sufficiency, social self-organization, ecological self-regulation, local interdependence, exposed to disturbance, reflective and shared learning, and honors legacy.

2.3. Data Collection and Analysis

The study covered 10 'Kebeles' where a very large portion of their respective areas and populations are within the watershed boundary. 'Kebeles' in Ethiopia are the lowest administrative units. Primary data were collected using three Focus Group Discussions (two farmers group and one group of agricultural experts working in the watershed) and a household survey. Literatures were used for a historical review of key changes in the watershed and to illuminate trends in the watershed agro-ecosystems.

FGD participants were purposefully selected based on the investigator's judgment. The farmers group of the FGD involved influential and informed members of the respective villages including village elders, religious leaders, and leaders of Youth and Women's' associations. The open ended questions for the Focus Groups included opinions about the features of their desired agro-ecosystem and to identify the most important factors that affect the resilience of agro-ecosystems to climate change.

Household survey was conducted on indicators identified by the FGD participants as 'most important' indicators of agro-ecosystem resilience to climate change in the study area. A total of 373 households were randomly selected from each Kebele proportionally using Kebele record (Table 5). James et al [60] sampling technique which allows a 5% acceptable error and 95% confidence interval level is employed. The head of the household participated in the survey. In situations where the head of the household was absent at the time of data collection, the wife or the eldest son/daughter of the family participated; whereas if the sampled household was closed the data collection was postponed and visited again.

Qualitative data generated through FGDs were analyzed concurrently with data collection using the technique of checking interpretations with participants [61]. The results of the household survey were analyzed with descriptive statistics, including means and percentages; independent samples 't' tests and multiple regression.

The method for assessing resilience from the set of variables is to first normalize the ranges of data [62] to ensure that they are comparable [63]. Different normalization procedures have been used for indices. For example, Piya, Maharjan & Joshi [64] normalized their vulnerability indicators by subtracting the mean from the observed value and dividing by the standard deviation for each indicator. Gobetibouo & Ringler [65] normalized each of their vulnerability indices to the range of values in the data set by applying the following general formula:

$$\textbf{Index Value} = \frac{\textbf{Actual Value} - \textbf{Minimum Value}}{\textbf{Maximum Value} - \textbf{Minimum Value}} \textbf{ X 100} \quad (1)$$

In this study the normalization procedure follows Gobetibouo & Ringler's [65] formula; and un-weighted additive model [62] was used to compute a summary score (the resilience indicator). Thus a household's farming system resilience index is the average of all normalized values of the indicators. In cases where there are more than one proxy variable for an indicator they are averaged to represent the behavior-based indicator (for example, verities of crops planted and varieties of land uses cultivated are averaged to represent diversity). The index does not show an absolute measurement of resilience; rather it is a comparative measure of the resilience of household farming systems with respect to the geographical setting in which they live (Upstream/Downstream).

Table 1: Variables hypothesized to influence agro-ecosystem resilience

Variables	Descriptions	Expected Sign	Hypotheses	Source
Gender	Sex of household head, dummy; 1 (female), 0 (male)	-	Female heads have less opportunities for exposure for managing resilience	Cutter et al. [66]
[Education	Education level of household head	+	More education favors faster knowledge acquisition and increases social-ecological resilience	Wamsler et al.[67]
Income sources	Number of income sources of the household	+	More diversified income sources allows diversification and increases resilience	Tompkins & Adger [58]
Age	Age of the household head	+	Older farmers have more experience and accumulation of knowledge to manage resilience	Kisauzi [68]

Perception	Number of weather related problems perceived by the household head	+	The more aware can manage resilience better	Sivell et al. [69]
Household size	Number of household members	+	Larger households have more family labor to manage resilience	Thomas et al. [40]
Land holding size	Total amount of land owned by a farm household	+	Farm households with lager farm size are more likely to diversify crops and enhance social-ecological resilience	Nguyen & James [70]
Soil fertility	Soil fertility of the farms of households, dummy; 1 (fertile), 0 (less fertile)	+	Fertile soils rely less on external inputs and increase Social-ecological resilience	Cabell & Oelofse. [34]
Farming experience	Number of years household head has worked as an independent decision maker	+	The more experienced the farm household head, the better he manages for resilience	Below et al. [71]

To identify the determinants of agro-ecosystem resilience a multiple regression analysis were conducted. The regression model was specified as:

$$Yi = \beta 0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_N X_N \qquad (2)$$

Where Y_i is the dependent variable (households' resilience index), β_0 is the **Y-** intercept; whereas β_1 - β_N is a set of coefficients to be estimated. X_1 - X_N are explanatory variables identified through literature review and FGDs. It was assumed that agro-ecosystem resilience depends on the socio-economic characteristics of farmers and their perception of weather related events.

3. RESULTS AND DISCUSSION

3.1. Quantitative Assessment and Analysis

The FGD participants' views of a resilient agro-ecosystem were consistent with indicators suggested in previous studies [42, 50-52]. Thus, eight agro-ecosystem resilience indicators were directly used. They include diversity, economic viability and self-sufficiency, social self-organization, ecological self-regulation, local interdependence, exposure to disturbance, reflective and shared learning, and honors legacy. Since the eight indicators were not directly observable proxy variables have been used. Crop varieties planted and land use types cultivated were used as proxies for 'diversity'. Data on indicators of 'economic viability and self-sufficiency' were gathered using proxy variables annual gross income of the farm household, percentage share of farm income within gross income and the number of months a farm household can be self-sufficient after the last harvest. Proxies for 'social-self organization' included the number of community groups households are involved in and participation in decision making. Number of perennials on farm was a proxy for 'ecological self-organization'. However, variety of crops planted and the variety of land uses cultivated could also be important to enhance ecological self-regulation capacity of an agro-ecosystem. Percentage share of local inputs and number of household members in labor exchange were the two variables selected for the indicator 'local interdependence'. Frequency of climate related shocks experienced by the household was a proxy variable for 'learning from disturbance'; and participation in trainings has been used as a proxy for 'reflective and shared learning'. For the indicator 'honors legacy', heirloom seed varieties maintained by the farm household and number of generations interacting in the household farm have been used as proxy variables.

Table 2. Summary of indicators of agro-ecosystem resilience with their respective proxy variables

Components of Resilience	Behavior-based Indicators	Proxy variables
Buffer capacity	Diversity	• Varieties of crops planted
		• Variety of land uses cultivated
	Economic viability and Self-sufficiency	• Annual gross income of the farm (in Birr)
		• Percentage of farm income within gross income
		• Number of months that the household can self-sufficient with their farm production
Self-organization	Socially self-organized	• The number of community groups households are involved in;
		• Ordinal score representing how involved respondents were in community decision-making processes (3 = has leadership role; 2 = has no leadership role but participate during meetings; 1 = passive member;
	Ecologically self-regulated	• Number of perennials on farm;
	Local interdependence	• Percentage share of local inputs;
		• Number of household members in labor exchange;
Learning and adaptation	Learning from disturbance	• Frequency of climate related shocks experienced
	Reflective and shared learning	• Number of trainings the farm household head participated in the last 5 years
	Honors legacy	• Heirloom seed varieties maintained
		• Number of generations interacting with the household farm for subsistence and income (5-if four or more generations interact with the family farm; 4- if three generations interact with the family farm; 3- if two generations interact with the farm; 2- if one generations interact with the agro-ecosystem; 1- if no interaction at all)

The analysis shows that upstream and downstream units of the watershed signifiantly differ in all of the indicators except for labor exchange, climate related shocks experienced and generations interacting.. The mean number of crop varieties planted in the upstream (4.60) is significantly higher than the downstream (3.06) ($P < 0.01$). The new system of irrigated farming in the downstream is creating a different land use system characterized by reduced diversity and increased specialization of on-farm crops. In recent years, land area used for maize and wheat production has been increasing; and the traditional crops like 'teff', have been on the decline in the lower watershed partly due to farmers' perception that maize and wheat provide higher yields and respond high to fertilizers compared to others. Statistically significant difference has also been observed in the verities of land use cultivated ($P < 0.01$). The average land use varieties cultivated in the downstream (1.87) is lower than the upstream (2.06). The traditional use of grasses for thatched roofs has drastically decreased in the downstream area due to the absence of grasslands. Natural forest cover has drastically decreased in the last thirty years. For its quick economic return, eucalyptus is dominating in the watershed. Due to market availability, downstream communities allocate considerable size of their croplands to eucalyptus.

If agro-ecosystems are to be resilient, farmers must have their needs met i.e. economic viability (Cabell and Oelofse, 2012). Measured by annual gross farm income and its share in total household income, significant differences have been exhibited in economic viability of agro-ecosystems between upstream and downstream areas of the watershed. Average annual farm income, as reported by farmers, is 35 510 Eth. Birr in the downstream whereas as it is 24 880 Eth. Birr in the upstream ($p < 0.01$). Thus, when income is considered, downstream households can withstand climate related shocks better than the upstream households. As another measure of economic viability of agro-ecosystems, share of farm income from the total income of households is greater in the upstream than in the downstream. Even though the sources of income are relatively more diversified in the downstream than the upstream, the average share of farm income of the upstream households (75.40 %) is significantly higher than their downstream counterparts (61.88) ($p < 0.01$). This reflects that the income earned from off-farm sources is lower compared to income generated from farming. From the agro-ecosystem perspective, it indicates that upstream communities depend less on off-farm income than the downstream communities and hence farmers in the upstream are likely to be stewards of their land more than the downstream farmers. The self-sufficiency of farm households was measured by the number of months households can use their farm produce to feed their families. The average number of months (12.09) in the downstream is significantly higher compared to the upstream (9.36) ($p < 0.01$). Statistically significant difference was also observed in the share of local inputs ($p < 0.01$).

Table 1: Independent samples 't' test on the proxy variables

Variables	Location	N	Mean	Std. Deviation	d.f	t
Crop planted	Downstream	285	3.06	.90	371	13.81*
	Upstream	88	4.60	.96		
Land use types	Downstream	285	1.8667	.78	371	1.965**
	Upstream	88	2.0568	.81		
Annual gross income	Downstream	285	35.51	9.33	371	9.421*
	Upstream	88	24.66	9.79		
Percentage of farm income	Downstream	285	61.88	10.70	371	9.269*
	Upstream	88	75.40	15.37		
Self-sufficiency	Downstream	285	12.09	2.12	371	11.090*
	Upstream	88	9.36	1.61		
The number of CBOs	Downstream	285	2.55	.84	371	1.824^{NS}
	Upstream	88	2.36	.85		
Participation in CBOs	Downstream	285	1.95	.73	371	3.956*
	Upstream	88	1.59	.81		
Perennials on farm	Downstream	285	127.15	142.84	371	2.979**
	Upstream	88	78.08	105.98		
Share of local inputs	Downstream	285	60.44	10.25	371	15.406*
	Upstream	88	79.20	9.09		
Labor exchange	Downstream	285	1.8842	.68	371	0.931^{NS}
	Upstream	88	1.9659	.83		
Climate related shocks	Downstream	285	2.1754	1.30	371	0.257^{NS}
	Upstream	88	2.2159	1.25		
Participation in Trainings	Downstream	285	3.08	.67	371	17.422*
	Upstream	88	1.56	.84		
Heirloom seed varieties	Downstream	285	2.9298	1.14	371	1.078^{NS}
	Upstream	88	3.0795	1.15		
Generations interacting	Downstream	285	1.6807	.72	371	0.920 ^{NS}
	Upstream	88	1.7614	.73		

Notes: * Significant at 0.01 level, ** Significant at 0.05 level, NS – Not significant

Perennial crops on farm, as reported by participants of the study, differed significantly ($p < 0.05$) between upstream and downstream watershed. A mean number of 127.15 perennial crops were mentioned by downstream farmers, compared to 78.05 in the upstream. Farm households grow coffee and fruits like sugar cane, lemon, orange, mango, banana and avocado. Most of the perennial crops are recently introduced fruit crops (mainly mango and avocado) and grow in the irrigated fields of the downstream area where water is in abundance and seedlings are easily available.

Measured as membership in farmers' organizations, a high degree of group interaction has been observed in the downstream than the upstream part of the watershed. The Koga Irrigation and Watershed Management has provided opportunities for farmers in the downstream areas to organize themselves in service cooperatives and saving and credit associations. Irrigation users' service cooperatives, saving and credit associations and one-five organizations were some of the local level organizations to which farmers are members. Membership to these organizations significantly differed between upstream and downstream communities ($p < 0.01$). The average number of organizations to which farm households are involved in is 2.55 in the downstream, and 2.36 in the upstream area. The awareness creation and community mobilization activities undertaken in the downstream areas could convince a number of farmers in the downstream area to become members of service cooperatives. These organizations have actually benefited members in terms of access to farm inputs, technologies, and technical assistance. The average share of local inputs is 60.44 % and 79.20% in the downstream and upstream households, respectively. This doesn't mean that downstream communities are using locally produced inputs more than the upstream but they use more external inputs than the upstream communities. This is because of their proximity to markets, better infrastructure, relatively secured availability of water which reduces the risk of crop failure and better income to buy external inputs compared to their upstream counterparts.

The capacity for learning and adaptation was assessed using participation in trainings as a proxy variable. The average number of times downstream households attended trainings is significantly higher than the upstream households, 3.08 and 1.56, respectively ($p < 0.01$). Related to the building of the dam, both government and non-governmental organizations have focused more on the downstream communities than the upstream communities. Even though, the Koga Irrigation and Watershed Management Project is supposed to work on both the downstream and upstream communities, the focus has been on the irrigation sub-sector of the project as a result of which more trainings are being given to the downstream communities than those of the upstream. Honors legacy was assessed using two proxy indicators namely: heirloom seed varieties (seed bank) and the number of generations interacting in the family farm. There is no any significant difference in the number of seed verities maintained. On average, 3 types of seed verities are maintained by both upstream and downstream communities. Maize and millet are the most common seed verities maintained as mentioned by participants of the study.

Similarly, there is no significant difference in the number of generations interacting in the farms of households. The average number of generations interacting in the farms is 1.68 and 1.76 for the downstream and upstream communities, respectively. This is partly related to the repeated land distribution that took place in Amhara Region in general and Mecha Woreda (District) in particular.

Table 2: Normalized Indicator values

	Watershed location	
Indicators	**Downstream**	**Upstream**
Diversity	32.23	52.44
Economic viability and Self-sufficiency	58.55	45.27
Socially self-organized	49.62	37.50
Ecologically self-regulated	24.25	14.74
Local interdependence	31.49	51.29
Learning from disturbance	23.51	24.32
Reflective and shared learning	61.61	31.14
Honors legacy	41.14	45.03

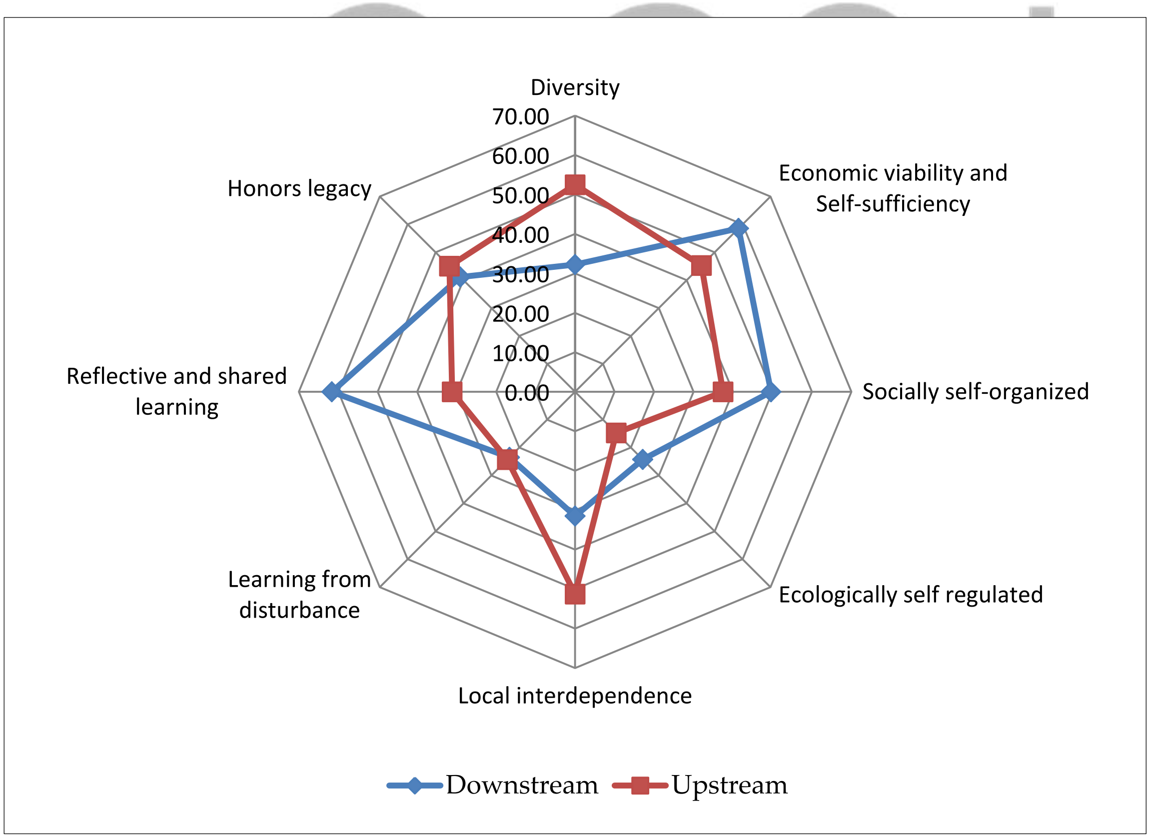

Figure 2: Comparison of the agro-ecosystems of the Upstream and downstream units of the Koga watershed on the resilience eight indicators

In general, the upstream watershed exhibited higher resilience in terms of diversity, learning from disturbance, honors legacy and local interdependence; whereas the downstream farming systems showed higher resilience in economic viability and self-sufficiency, social self-organization, ecologically self-regulation and reflective and shared learning. However, the independent sample t- test calculated showed that the downstream farming systems with the mean percentage value of (52%) is more resilient to climate related disturbances compared to its upstream counterpart with the mean percentage value of (30%), ($P < 0.01$).

Table 3: Independent sample t test for resilience using normalized values

	Location of the household in the watershed	N	Mean	Std. Deviation	d.f	t	P
Resilience Index	**Downstream**	285	52	16.66796	371	11.323	0.000
	Upstream	88	30	13.32378			

3.2. Determinants of Agro-ecosystem Resilience to climate change

A multiple regression analysis was conducted with the normalized values of agro-ecosystem resilience index as the dependent variable and household level socio-economic variables as independent (explanatory variables) to pinpoint the determinants of agro-ecosystem resilience. The descriptive analysis of the independent variables helped to see variations in the socio-economic characteristics between the two units of the Koga watershed.

Downstream units scored higher means than the upstream in all of the variables except for the total land area possessed. The relatively low mean size of farm land possessed in the downstream is primarily due to the relatively high density of population and the construction of the Koga Dam which reduced farm plots in the command area to a considerable size. The average number of formal education years of household heads of respondents in the downstream which is 2 years is higher than that of the upstream which is 1.34 years. Whatever the level of education is, household heads with higher number of formal education have better level of managing their farms, easily understand and willing to adopt extension packages.

Table 4: Household-level socio-economic variables expected to be significantly correlated with agro-ecosystem Resilience

Variables	Measure	Downstream	Upstream
Female headed households	Percent	24.21	19.31
Average age of household head	Mean of years	43	37
Number of formal education years of the household head	Mean of years	2.00	1.34
Number of income sources	Mean number of income sources	1.71	1.34
Number of weather related changes perceived by the household head	Mean number of changes perceived	2.9	2.7
Size of the household	Mean number of household members	6.05	4.83
Total land area (ha) the farm household possesses	Mean hectares	1.41	1.69
Soil fertility of the farm (Ordinal value ranging from 1= Not productive to 5 = Very fertile	Mean of value	3.67	3.21
Farming experience (number of years household head has worked as an independent decision maker)	Mean number of years	18.96	13.63

The number of income sources is very important for agro-ecosystem resilience (Tompkins & Adger, 2004). More diversified income sources allow investment for diversification and conservation of farms and increases resilience. In this variable too, downstream households scored better than their upstream counter parts. The mean number of income sources in the downstream is 1.74 compared to 1.34 in the upstream. Petty trading, , farm labor and wage labor and traditional handicrafts and selling of local drinks (usually practiced by women) are some of the non-farm income sources mentioned by participants of the study. Household size which relates to working potential for land management is also important for agro-ecosystem resilience. The mean household size of the downstream household is higher than the upstream households, 6.05 and 4.83, respectively. Farming experience which is represented by the number of years household heads worked as an independent decision maker also influences resilience. Farmers with many years of farming experience can operate agricultural activities that enhance resilience. With 18.96 years of average experience, the downstream households have better farming experience than the downstream households with a mean value of 13.63 years. Soil fertility of the farms of households was assessed using the ratings of respondents on a likert scale ranging from ‘1’ (Unproductive) to ‘5’ (Very fertile). The average value of the downstream farms (3.67) suggests that the farms are ‘fertile’ and similar value of the upstream which is 3.21 indicates that it is ‘somewhat fertile’.

Table 5: Independent Sample t test for explanatory variables

Variables	Location	N	Mean	Std. Deviation	d.f	t
Number of formal education years of the household head	Downstream	285	2.00	1.53	371	3.889*
	Upstream	88	1.34	0.71		
Number of income sources	Downstream	285	1.72	0.70	371	4.655*
	Upstream	88	1.34	0.52		
Age of the household head	Downstream	285	42.99	7.09	371	6.664*
	Upstream	88	37.39	6.23		
Number of perceived changes in weather events	Downstream	285	2.91	1.63	371	1.032^{NS}
	Upstream	88	2.70	1.72		
Size of the household	Downstream	285	6.06	2.07	371	5.080*
	Upstream	88	4.83	1.68		
Total land area (ha) the farm household possesses	Downstream	285	1.41	0.48	371	4.750*
	Upstream	88	1.69	0.50		
Soil fertility of the farms of households	Downstream	285	3.67	0.91	371	4.203*
	Upstream	88	3.24	0.55		
Farming Experience	Downstream	285	18.96	6.29	371	7.074*
	Upstream	88	13.63	5.82		

Notes: * Significant at 0.01 level, NS – Not significant

The independent sample t test conducted on the explanatory variables shows that the two units of the Koga watershed differed significantly ($P < 0.01$) in all of the socio-economic variables hypothesized to influence agro-ecosystem resilience.

Before running the regression, the multicollinearity of the explanatory variables was considered. Since the tolerances of all the predictor variables were far in excess of 0.1, multicollinearity was not a problem (Landau and Everitt, 2004). Thus, all the variables were entered into the regression model. All the predictors, except age and size of the household, predicted agro-ecosystem resilience significantly ($P < 0.05$). The multiple regression model was statistically significant, $F (9, 363) = 43.488$, $P = 0.001$). With an R^2 value of 0.51, the model explained 51% of the total variance in agro-ecosystem resilience. Yet, substantial amount of variance (49%) is not explained by the model indicating that a considerable number of potential predictors of agro-ecosystem resilience are not included to the model. Nevertheless, this is expected in the study of social-ecological systems which are naturally multifaceted.

Table 6: Socio-economic factors influencing agro-ecosystem resilience to climate change

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-2.945	5.920		- 4.97	.019

Sex of the household head	.771	1.609	.018	4.79	.032
Number of formal education years of the household head	.766	.503	.058	15.22	.. 029
Number of income sources	1.707	1.004	.063	16.99	.040
Age of the household head	.198	.155	.078	1.276	.203
Number of perceived changes in weather events	.817	.411	.073	19.88	.048
Size of the household	.072	.533	.008	1.36	.892
Total land area (ha) the farm household possesses	-1.677	1.360	-.046	-12.33	.018
Soil fertility of the farms of households	1.443	.820	.067	17.59	.049
Farming Experience	1.790	.125	.637	14.372	000

The standardized regression coefficients showed that farming experience by far most strongly determined agro-ecosystem resilience to climate change, followed by age of household head, soil fertility, and perception of changes in weather related events, number of income sources, education, farm land possession, gender and household size.

4. CONCLUSION

The results of the study showed significant differences in many of the agro-ecosystem resilience indicators between the Upstream and Downstream Koga Watershed. It is observed that in terms of diversity, local interdependence, learning from disturbance and in maintaining the legacy of the past the upstream watershed are better compared to their downstream counter parts. The downstream agro-ecosystem is in a better position in terms of economic viability and Self-sufficiency, social and ecological self-regulation and reflective and shared learning. However, when the overall resilience of the agro-ecosystems of the two units of the watershed is considered, the upper watershed agro-ecosystem is less resilient than the downstream agro-ecosystem. Thus, while considering possible measures to build the agro-ecosystems of the watershed as a whole, it should be a priority for stakeholders to enhance the resilience of agro-ecosystems to climate change in the Upstream Koga Watershed.

The two sections of the watershed significantly differed in many of the socio-economic variables that were expected to influence agro-ecosystem resilience. The downstream households are by far better in their socio-economic status compared to the upstream households. These socio-economic variables significantly predicted agro-ecosystem resilience. Farming experience by far most strongly determined agro-ecosystem resilience to climate change, followed by age of household head, soil fertility, and perception of changes in weather related events, number of income sources, education, farm land possession, gender and household size.

Acknowledgment

We are very much grateful to Addis Ababa University and Association of African Universities (AAU) for the financial support.

References

[1]. Dixon, J. L. and Lindsay C. Stringer (2015). Towards a Theoretical Grounding of Climate Resilience Assessments for Smallholder Farming Systems in Sub-Saharan Africa. Resources 2015, 4, 128-154.

[2]. Di Falco, S., and J. P. Chavas. (2008). Rainfall shocks, resilience, and the effects of crop biodiversity on agroecosystem productivity. Land Economics 84(1):83-96

[3]. Bohensky, E. L. (2008). Discovering resilient pathways for South African water management: two frameworks for a vision. Ecology and Society, 13(1): 19. [online] URL: http://www.ecologyandsociety.org/vol13/ iss1/art19/

[4]. Carpenter, S.R., Westley, F. & Turner, M.G. (2005). Surrogates for Resilience of Social-Ecological Systems. *Ecosystems* 8: 941-944.

[5]. James, E., II., Joe, W. & Chadwick, C. H. (2001). Organizational Research: Determining Appropriate Sample Size in Survey Research. Information Technology, Learning, and Performance Journal, 19 (1), 43-50.

[6]. Ezzy, D. (2002).Qualitative analysis: practice and innovation. Allen & Unwin: Sydney.

[7]. Ibarraran, M,E., Malone, E.L. and Bernekert, A.L. (2009). Climate Change Vulnerability and Resilience: Current Status and Trends for Mexico. Environment, Development and Sustainability.

[8]. Vincent, K. (2004). Creating an index of social vulnerability to climate change for Africa. Working Paper 56. Norwich: Tyndall Center for Climate Change Research.

[9]. Piya, L., Maharjan, K. L. & Joshi, N. P. (2012). Vulnerability of rural households to climate change and extremes: Analysis of Chepang households in the Mid-Hills of Nepal. Selected Paper prepared for presentation at the International Association of Agricultural Econo-

mists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August, 2012. Gbetibouo, G. A. & Ringler, C. (2009). Mapping South African Farming Sector Vulnerability to Climate Change and Variability. IFPRI Discussion Paper 00885. Development Strategy and Governance Division. Washington, D.C.: International Food Policy Research Institute.

[10]. Cutter, S.L., Boruff, B.J. & Shirley. W.L. (2003). Social vulnerability to environmental hazards. Social Science Quarterly 84 (2): 242–261.

[11]. Wamsler, C., Brink, E. & Rentala, O. (2012). Climate change, adaptation, and formal education: the role of schooling for increasing societies' adaptive capacities in El Salvador and Brazil. Ecology and Society, 17(2): 2[online] URL: 2.http://dx.doi.org/10.5751/ES-04645-170202

[12]. Tompkins, E. L., and W. N. Adger. (2004). Does adaptive management of natural resources enhance resilience to climate change? Ecology and Society 9 (2): 10. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art10/.

[13]. Kisauzi, T., Mangheni, M .N, Sseguya, H. & Bashaasha, B. (2012). Gender dimensions of farmers' perception and knowledge on climate change in Teso Sub-region, Eastern Uganda. African Crop Science Journal, Vol. 20, Issue Supplement, 275 – 286.

[14]. Sivell, P, M., Reeves, S. J., Baldachin, L. & Brightman, T. G. (2008). Climate Change Resilience Indicators. Client Project Report.

[15]. Thomas, D., Osbahr, H., Twyman, C., Adger, W. N., Hewitson, B. (2005). ADAPTIVE: adaptations to climate change amongst natural resource-dependant societies in the developing world: across the Southern African climate gradient. Tech. Rep. 35. Tyndall Cent. Clim. Change Res., Univ. East Anglia, Norwich, UK

[16]. Nguyen, K. V. & James, H. (2013). Measuring household resilience to floods: a case study in the Vietnamese Mekong River Delta. Ecology and Society 18(3): 13. http://dx.doi.org/10.5751/ES-05427-180313.

[17]. Cabell, J. F. & M. Oelofse, M. (2012). An indicator framework for assessing agroecosystem resilience. Ecology and Society 17(1): 18. http://dx.doi.org/10.5751/ES-04666-170118

[18]. Below, T. et al. (2012). Can farmers' adaptation to climate change be explained by socioeconomic level variables? Global Environmental Change, 22 (1), 223-235.

[19]. Moges Kidane Biru1, Amare Sewnet Minale, Alemu Bezie Debay (2015). Multitemporal Land Use Land Cover Change and Dynamics of Blue Nile Basin by Using GIS and Remote Sensing Techniques, North-Western Ethiopia. International Journal of Environmental Sciences Vol. 4 No. 2. 2015. Pp. 81-88

[20]. Bishop, K., Gebrehiwot, S. and Taye, A. (2010) Forest Cover and Stream Flow in a Headwater of the Blue Nile: Complementing Observational Data Analysis with Community Perception, Ambio,39 (4), 284-294.

[21]. Shibru Tedla and Kifle Lemma. (1998). Environmental management in Ethiopia: Have the National Conservation plans worlzed? Environmental Forum Publications Series No 1. Organization for Social Science Research in Eastern and Southern Africa (OSSREA).

[22]. Aklilu Agidie, Belayneh Ayele, Alemayehu Wassie, Kiros M. Hadgu, Ermias Aynekulu & Jeremias Mowo. (2014). Agroforestry Practices And Farmers' Perception in Koga Watershed, Upper Blue Nile Basin, Ethiopia. Agriculture and Forestry, Vol. 60. Issue 2: 177-192.

[23]. Yeshaneh, E., Wagner, W., Exner-Kittridge, M., Legesse, D. & Blöschl, G. (2013). Identifying Land Use/Cover Dynamics in the Koga Catchment, Ethiopia, from Multi-Scale Data, and Implications for Environmental Change. Int. J. Geo-Inf. 2013, 2, 302-323.

[24]. Lane, P.N.J., Morris, J., Ningnan, Z., Guangyi, Z., Guoyi, Z., Daping, X., 2004. Water balance of tropical Eucalyptus plantations in south-eastern China. Agricultural and Forest Meteorology, 124, 253–267.

[25]. Bergamini, N., et al. (2013). Indicators of Resilience in Socio-ecological Production Landscapes (SEPLs), UNU-IAS Policy Report.

[26]. Speranza, C., Wiesman, U. and Rist, S. (2014). An indicator framework for assessing livelihood resilience in the context of social-ecological systems. Global Environmental Change, 28, 109 -119.

[27]. Jacobi, J., Schneider, M., Mariscal, M. P., Huber, S., Weidmann, S., Bottazzi, P. & Rist, S. (2015). Farm Resilience in Organic and Nonorganic Cocoa Farming Systems in Alto Beni, Bolivia, Agroecology and Sustainable Food Systems, 39:7, 798-823, DOI: 10.1080/21683565.2015.1039158