The Impact of forest cover on potable water treatment costs: Panel evidence from Ethiopia

Dawit Woubishet[1] and Amare Fentie[2]

Abstract

Water purification is one of the regulating services of forest ecosystem. Empirical assessment on the impact of forest cover on chemical cost to treat water is lacking in developing countries like Ethiopia. This study is therefore conducted to assess the impact of forest cover on the water purification services using panel data of eight water treatment plants in Ethiopia. The panel data was collected from regional Water, Sewerage and Sanitation offices and the forest cover data extracted from Global Forest Change dataset (2002-2014). Panel fixed effect regression was applied for the purpose of singling out the effect of forest cover on water treatment chemical costs (for aggregate chemical cost to treat water and separately for costs to Aluminum Sulphate). We analysed the effect of forest cover on water treatment chemicals cost at different spatial scales: watershed level, upstream forest cover and forest cover with different buffer distances. Results indicated that forest cover both at the watershed and upstream level has a significant effect on water treatment chemical cost. In addition, forest cover effect on costs to treat water with different buffer distances revealed that lower buffer distance forest cover contributes significantly to the reduction of treatment chemical costs as compared to the furthest buffer. Thus, this study finding highlighted that protecting forests enhances water quality and reduces the chemical costs incurred to treat potable water.

Key Words:, Water treatment cost, water purification, Forest, Fixed effect, Ethiopia

---

[1] *Research fellow at Environment and Climate Research Center (ECRC), Ethiopian Development Research Institute (EDRI), email: dawitwoubishet@yahoo.com*

[2] *Research officer at Environment and Climate Research Center(ECRC), Ethiopian Development Research Institute (EDRI), email: ame.fentie@yahoo.com*

1. Introduction

Advancements in science and technology have enabled water utilities to effectively treat most known contaminants from drinking water sources and provide safe drinking water. However, the advancements have contributed to a movement away from protecting and managing the water source areas, and the notion that the quality of raw water supplies is less important (Ernest 2004; Ernst et al. 2004).The continued conversion and development of forest land pose a serious threat to the ecosystem services derived from forested landscapes. The water purification service of ecosystems dictates that the water from forested land and other ecosystems is cleaner than water that comes from other land uses like agricultural, urban and industrial landscapes (Vincent et al. 2016);Ernst,2004).

Ensuring access to clean water and sanitation is one of the 17 global goals that make up the 2030 agenda for sustainable development. Water scarcity affects more than 40% of the world population and it is projected to increase due to the rise of global temperatures as a result of climate change (UNDESA 2014). Protecting and restoring water-related ecosystems such as forests, mountains and wetland is essential to mitigate water scarcity, unsafe water access and water availability. Protection and restoration of clean water sources such as forests reduce the costs associated with water treatment. Water purification is one of the regulating services of ecosystems provided by the ecosystem to human beings (MEA 2005; TEEB 2010). Land use changes for timber harvesting operations, agriculture based plantations, road construction, housing development; conversion of forest land to other land uses will lead to diminishing water quality. As well, contamination of water streams results in higher costs to treat water because additional chemical is needed to treat water (Rahim & Shahwahid 2011)..

A notable example for this comes from the synthesis of (TEEB 2010) report and it was the decision by the New York City authorities to pay landowners in the Catskill mountains to improve farm management techniques and prevent run-off of waste and nutrients into nearby water courses in order to avoid building expensive new water treatment facilities, which otherwise would have been required by federal regulations. The water purification services of *the watersheds can reduce the water treatment costs. A study by (Ernest 2004) showed that 50-55% of the variation in operating water treatment cost can be explained by the percentage of forest cover in the water source area. The same study finds that for every 10 % increase in forest cover in the source area of the water, result in treatment and chemical costs decreased approximately by 20 %.*

Several empirical Studies (Moore & McCarl 1987; Holmes 1988) indicated that water treatment costs are lower when the raw water processed by water treatment plants (WTPs) was less turbid (contained lower levels of suspended and dissolved solids). Other related studies also found that run off from forests is cleaner than run off from other land uses implying that forests can provide economically valuable water purification service (Dunne and Leopold, 1982; Hewlett, 1982; Carlson et al, 2014).

Well managed ecosystems are resources with immense economic and ecosystem values to both the local communities and the rest of the world(Hanson et al. 2011). Societies have created strong cultural links with forests, and it is widely assumed that forests help to maintain a constant supply of good quality water. A large portion of the value of tropical forests arises from regulating services, such as water purification, carbon storage, erosion prevention, and pollution control. In many valuation studies, these regulating services account for around two-thirds of total economic value. In contrast, the supply of food, timber, genetic and other materials typically accounts for a relatively small share of forest value, although these are the benefits on which perceptions of the economic importance of forests are often based (TEEB 2010). Thus, for effective water management, understanding the relationship between land use and water quality as well land use impact on water treatment cost play significant role.

2. The value of forests in Ethiopia

In East Africa, the economic value of forests is underestimated by policy makers, planners and resource managers which resulted in low priority for the sector despite in continuous degradation. But, currently in Ethiopia, the forest sector is identified as one of the four pillars of the country Climate Resilient Green Economy (CRGE) strategy and has the largest potential in reducing emissions and increasing climate resilience in the country (FDRE 2012). Despite the forest sector significant role, the economic value of forest ecosystem services is not adequately captured in the national account of the country. Forests are widely recognized as a land cover for the protection of water resources. Forests control erosion, improve water quality and regulate water flows in catchments (Muys etal 2014).

The contribution of forests to GDP is highly underrated in Ethiopia. A study by Smith et al (2016) found Ethiopia's forests generated economic benefits in the form of cash and in-kind income equivalent to 120 billion Ethiopian birr (which is around 18 billion USD) with additional non market benefits of 2.4 billion Birr in relation to willingness to pay to maintain forest cover. Studies about the valuation of forests for their ecosystem services are very scant, there are only few micro level empirical studies undertaken which assessed the economic value of forests in Ethiopia (Ayenew and Tesfay, 2015;Gardei, 2006; Ayenew et al, 2015; Tilahun et al, 2011; Smith et al, 2016; Muys et al, 2014). These empirical works emphasized on the value of ecosystem services of forest including water related services. Similarly Ayenew et al,(2015) and Tilahun et al(2011) applied contingent valuation method to estimate the willingness to pay of the communities to protect the forest and evaluate the economic value forest. However, the value of the regulating services of forest ecosystems (i.e. for water purification) is not well addressed by previous empirical works conducted in Ethiopia.

This paper is one of the very few in developing countries that deal with the impact of forest cover on chemical costs to treat water. Despite the land use changes from forests to agricultural land, housing, grazing, and other land use types in Ethiopia, to the best of our knowledge there *is no rigorous empirical study about the impact of forest cover on the chemical costs of treatment plants in Ethiopia though access to safe drinking water and sanitation is a prior agenda in environmental policies of the country.*

Methodology

This paper followed an approach applied by Vincent et al. (2016), to analyse the effect of forest land use on water treatment chemicals cost using econometric evidence. The treatment plants cost function used here based on the theory of cost functions to value environmental inputs (McConnel and Bockstael 2005, Vincent 2011, Freeman et al 2014, Vincent et al 2016). Short run cost functions of firms which use one or more un-priced environmental inputs include four types of variables. These are; i) the firm's output level, ii) prices paid by the firm for labor and other non-environmental inputs, iii) the quantity of capital and other fixed factors, and iv) the quantity of environmental inputs used by the firm. Fixed effects regression applied to assess the impact of forest cover on chemical cost to treat water. The panel nature of our data can serve us to control unobserved confounders that might affect the true effects of forest land cover on chemical costs. Since chemical costs are operating costs, the study analyzed the short run effects of forest cover change on chemical costs. The panel fixed effects model can be specified as follows:

$$\ln(C_{it}) = L_{iy}\beta + \alpha \ln(q_{it}) + \gamma_1 \ln(r_{it}) + \gamma_2(\ln(r_{it}))^2 + \gamma_3 \ln(tem) + C_i + u_{it}$$

where C_{it} *stands for the dependent variable; water treatment cost (disaggregated by chemical type used) and we estimated the given fixed effects model for the dependent variable (chemical cost),*L_{iy}*refers a forest land cover variable around the water treatment plants' catchment which is varied by year,* q_{it} *and* r_{it} *represent treated water volume and rainfall*[3]*(both varied by year and month). Theoretically, rainfall increases sediment loads in rivers in tropical regions by eroding soil and transporting sediment (Dunne 1979;Abdul Rahim and Zulkifli 2004). In addition there is also evidence that treatment cost is higher during wet periods (Sthiannopkao et al, 2007; Dearmont et al. 1998). Dilution causes contaminants around the source water to be lower when stream flow is high. Dilution effect similarly could cause treatment costs to be lower when*

---

[3] *Rainfall and land use variables refer to the water treatment plants' catchment.*

rainfall is higher. It is hypothesized that the dilution effect would dominate the soil erosion effect and reduce cost at lower, less erosive rainfall levels ($\gamma_1 < 0$), and increases the cost at higher level of rainfall ($\gamma_2 > 0$).tem refers to the average annual temperature around each treatment plants. Fixed effects are also included to control time invariant water treatment plant characteristics (C_i), and water treatment plant invariant annual characteristics. The major chemicals used to treat water in each treatment plants are Aluminum Sulphate, lime, and chlorine. The chemical cost represents the costs incurred for chemicals. Since fixed effect estimation is more robust to selection bias problems than random effect estimator, fixed effects model is employed for our analysis (Kennedy, 2008).

Data sources and description of variables

This study covers observations from eight water treatment plants in Ethiopia for the year 2002-2014. The treatment plants include two of the major water treatment sites of the capital city, Addis Ababa ("Gefersa" and "Legadi") and six other treatments plants of regional state cities (Hawassa, Jimma, Gondar, Yirgalem, Shashemene and Dilla). Treatment plant level data: like water volume, rainfall, average temperature and costs of chemicals for water treatment are collected from respective water treatment plants of the water, sewerage and sanitation bureaus. For the land cover variable, the study used global Forest Change (2000-2014 high resolution land cover map to identify forest cover and the different buffered forest that covers around the treatment plants using the Global Forest Cover dataset (Hansen *et al.* 2013). The forest cover at different land cover buffer zones, upstream parts of the catchment, and the whole catchment area were used to assess the impact of forest cover on the cost of chemicals to treat water. The nature of the data is panel that ranges from 2002 to 2014. *The buffer distances from the water treatment plants ranges from 2.5 kilometers to 30 kilometers.*

Results and discussion

Descriptive statistics

The main explanatory variables that are included in the analysis are transformed in to their logarithmic forms for the purpose of normality and ease of interpretation. These variables are the forest cover at the watershed level, upstream forest cover (in square kilometers), treated water volume (in cubic meters), average annual precipitation and average annual temperature of the treatment plants watershed. These variables are treatment plant level variables and ranges from year 2002 to 2014.

Table1: Summary statistics

	Water treatment plants (N=8)			
Variables	**Mean**	**Std. dev.**	**min**	**max**
Aggregate chemical cost(cost in Birr)	*2672827*	*3644481*	*119736*	*1.66e+07*
Aluminium Sulphate (cost in Birr)	*1476627*	*1972592*	*54350*	*1.40e+07*
Average annual precipitation (in mm)	*1156.455*	*200.0567*	*655.5*	*1780.5*
Watershed area(sq. km)	*1014.056*	*1601.812*	*73.97*	*5152.3*
Watershed forest area (in sq. km)	*210*	*353*	*0.47*	*1120*
Upstream forest area(in sq. km)	*204*	*189*	*0.14*	*574*
Number of customers	*31781*	*56960.42*	*1380.372*	*213383.3*
Treated water volume(in cubic meter)	*9232181*	*1.88e+07*	*34042.65*	*6.06e+07*
Total water consumption (in cubic meter)	*5651713*	*1.10e+07*	*47075.52*	*3.80e+07*
Average annual temperature (^{0}C)	*20.5*	*2.85*	*16.2*	*27.1*

The summary statistics of key variables presented in Table 1. The mean annual aggregate chemical cost of the water treatment (which includes Aluminum Sulphate, chlorine, Calcium hyper chlorite and lime) is about 2.7 million Ethiopian Birr. Aluminum Sulphate[4] which takes the largest share has an average cost of 1.5 million Ethiopian Birr. The mean annual rainfall is also around 1156 millimeters and ranges from the minimum of 655.5 to a maximum value of 1780.5 millimeters. This mean annual rainfall refer to the water treatment plants' catchment area. Average watershed area (in square km) and forest area (for both watershed and upstream) are

---

[4] *Unlike other treatment chemical costs, the cost of Aluminum Sulphate is reported here due to its significant share compared to the costs of other treatment chemicals.*

also reported with a mean of 210 and 204 square kilometers respectively. Like the data for annual rainfall and temperature, land use data variables (watershed and forest cover) refer to the catchment area. The mean annual treated water volume and water consumption in each treatment plants is respectively 9,232,181 and 5,651,713 cubic meters.

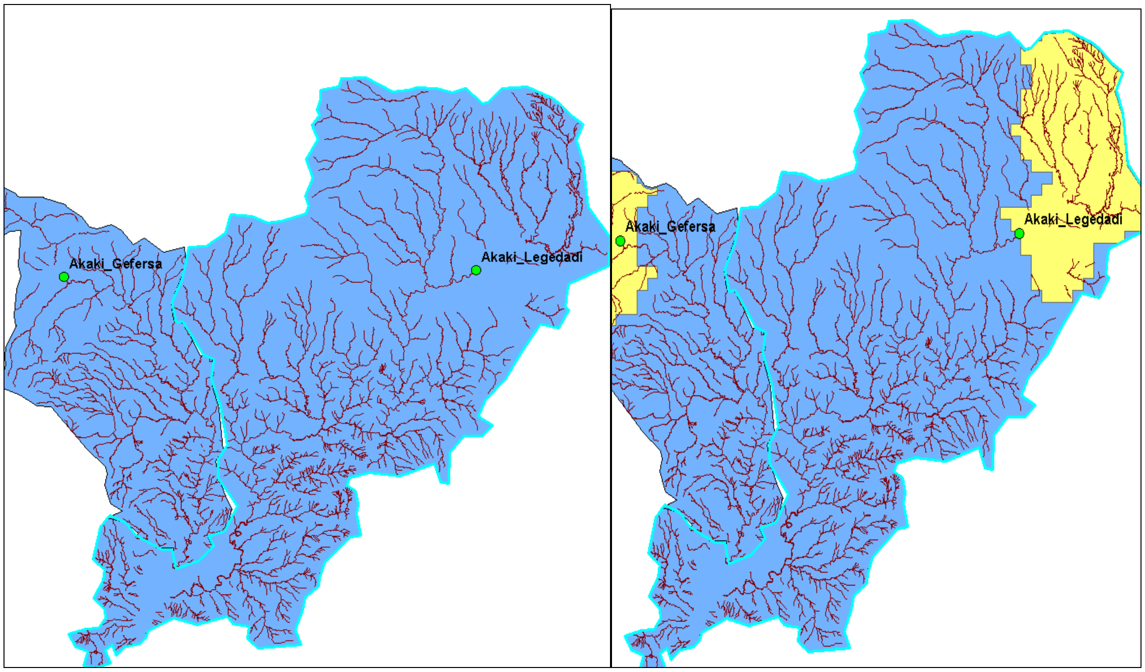

Figure 1A: whole watershed of the two plants

Figure 1B: The upstream area of the water treatment plants watershed (in yellow)

Figure 1: The watershed and upstream area of Gefersa and Legedadi treatment plants

For analytical purposes, the study used three basic land use scenarios; the first scenario is analysis of the effects of the forest cover at the watershed level, the second analytical scenario is the effects of the upstream forest cover, and the last scenario dealt with the impact of forest cover with different buffer distances around the water treatment plants. To illustrate, we presented the map for the two water treatment plants found in Addis Ababa; Akaki-Gefersa and Legedadi water treatment plants. Figure 1 shows the whole watershed and the upstream parts of the watershed (indicated in yellow) of the two water treatment plants. In Figure 2, the watershed and upstream area of the water treatment plants with different buffer distances with range of 2.5 km, 5km, 10 km, 15km, 20km, 25km and 30km.

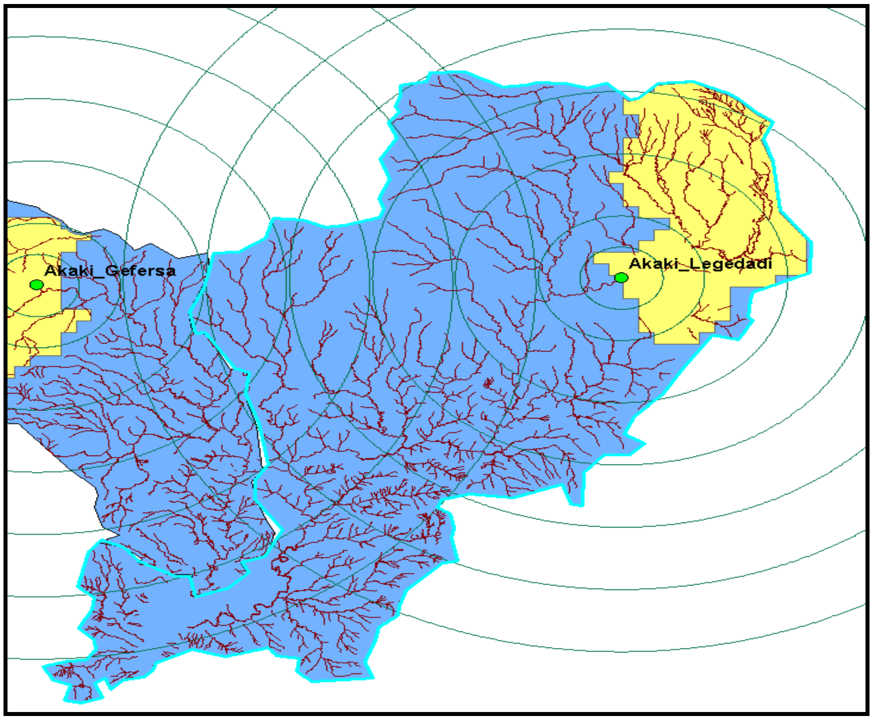

Figure 2: Intersected area between water treatment plant with buffers, upstream and the watershed

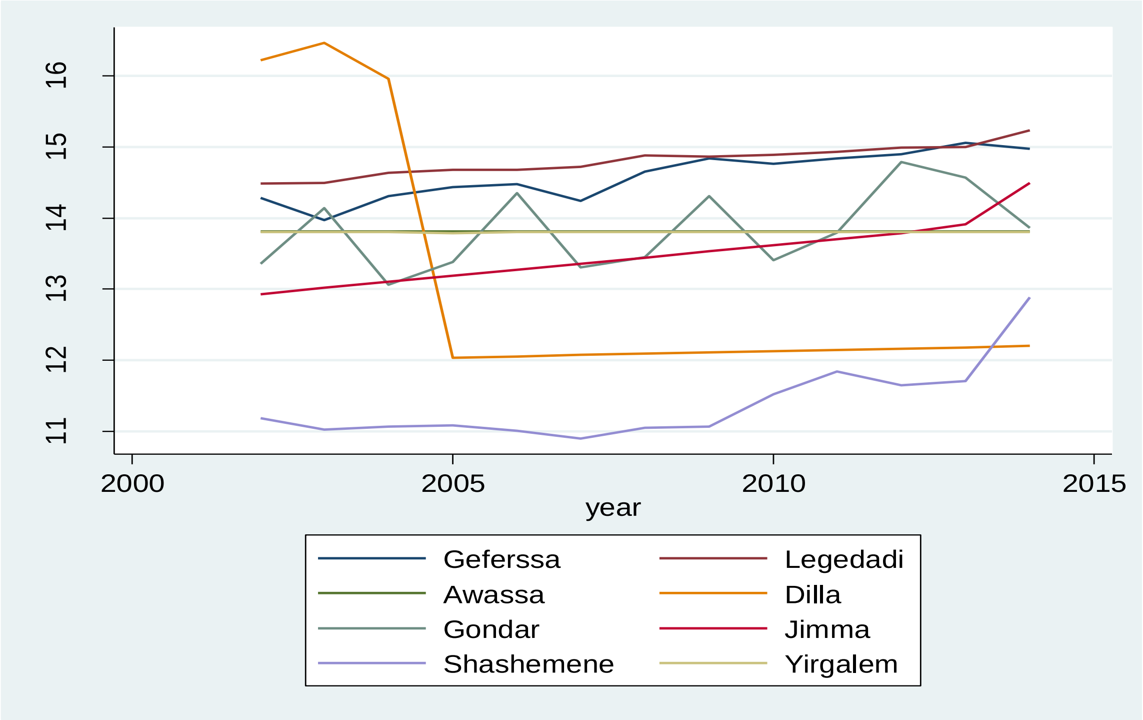

Figure 3: The variation of treatment chemical cost (Aluminum Sulphate in logarithmic form) over time

As Figure 3 depicts, the treatment chemical cost (for Aluminium Sulphate) varied across each treatment plants, it might depend on the size and water treatment chemical need for the plants. The water treatment plants respectively are Geferesa, Legedadi, Hawassa, Dilla, Gonder, Jimma, Shashemene and Yirgalem. The cost of Aluminium Sulphate shows an increasing trend for most of the water treatment plants though the rate differs across treatment plants.The variation in aggregate treatment chemical costs has almost the same trends with the cost of Aluminum Sulphate presented in Figure 4.

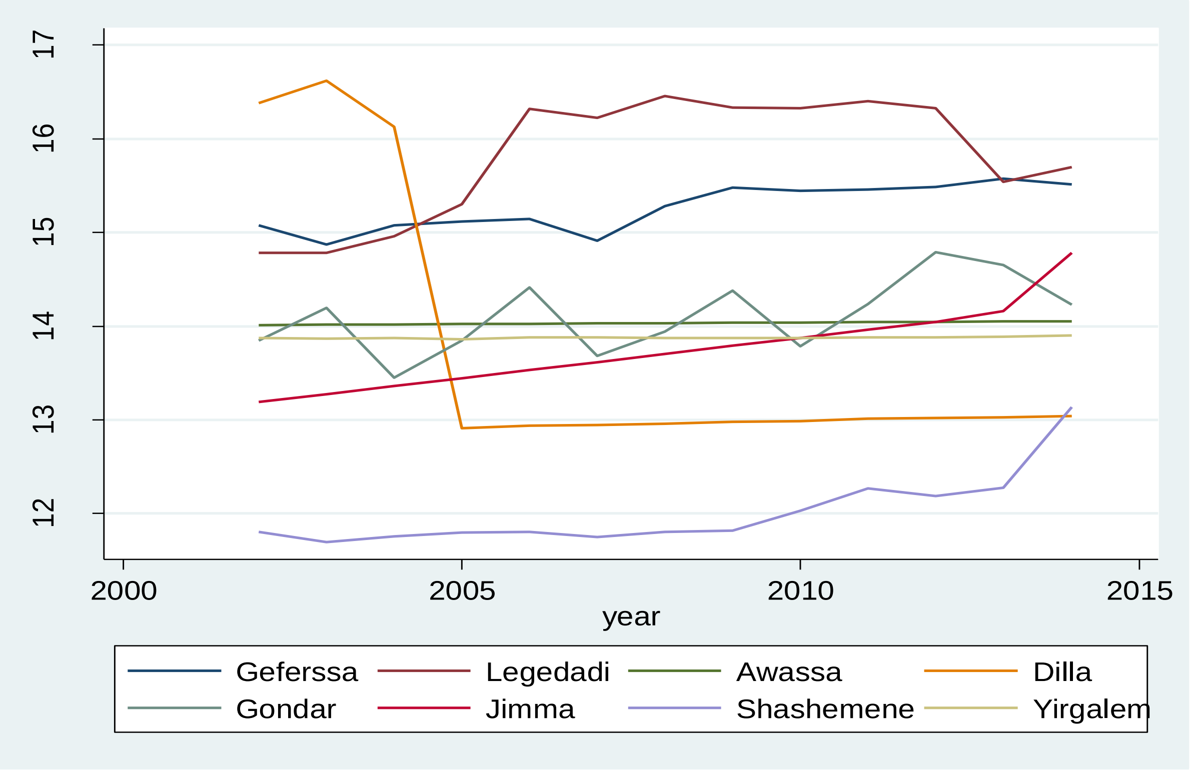

Figure 4: Variation in aggregate chemical cost across treatment plants

The Impact of watershed forest cover on water treatment chemical costs

Given the panel nature of our data, we run a panel fixed effects regression and found relevant relationships between the aggregate water treatment chemical costs[5]. The effect of forest cover on water treatment chemical cost[6] is estimated based on three basic scenarios. First, we estimated the impact at the watershed level. Second, we tried to estimate the effect of upstream forest cover on water treatment costs and the third scenario is forest cover with

---

[5] The aggregate chemical cost is the sum of the costs of main treatment chemicals used in each of the 8 treatment plants. The three main treatment chemicals used are Aluminiumsulphate, chlorine, calcium hyperchlorite and lime. The cost is expressed in Ethiopian Birr.

[6] Water treatment chemical costs refer to both aggregate chemical cost and the cost for Aluminum Sulphate.

different buffer distances. Aggregate chemical cost to treat water is used as short run operating cost which is comprised of main treatment chemicals. In addition to the aggregate chemical cost, the effect on the cost of one of the treatment chemical (i.e. Aluminum Sulphate) is also analyzed. The main reason for the inclusion of the cost of Aluminum Sulphate separately in the regression analysis is that all treatment plants used it as main treatment chemical and takes significant share from the total cost.

All variables are in logarithmic form and can be directly interpreted as elasticity (responsiveness). In this section, we analysed the effect of forest cover on water treatment chemical costs at the watershed level. The logarithm of water treatment chemical costs (aggregate chemical cost and Aluminum Sulphate) is used as dependent variables. Watershed forest area, treated water volume at each treatment plant, average annual temperature and annual rainfall are used as independent variables. The watershed forest cover has significant negative impact on the aggregate water treatment chemical costs. It also affects the cost of Aluminum Sulphate significantly (at 5% level of significance). The water treatment chemical cost decreases significantly when the forest cover increases at watershed level. This finding is consistent with notable works which are conducted to analyze the relationship between forest cover and water treatment costs (Vincent et al, 2016; Ernst, 2004; Ernst et al, 2004). As expected, the effect of rainfall on water treatment chemicals costs is negative at lower level of rainfall and positive at higher level of rainfall and the dilution and soil erosion effects[7] holds (its effect is significant at 5% for Aluminum Sulphate treatment chemical as indicated in Table 3).

Table 3: Fixed effects regression result at watershed level

Variables	*Panel fixed effect (Dependent : Log of aggregate treatment cost)*	*Panel fixed effect (dependent: log of Aluminum Sulphate)*
lnwatsh_frsta	*-8.30***(3.06)*	*-8.34**(3.47)*
Inproduc_tp	*-0.40(0.25)*	*-0.52*(0.28)*
lnaver_tem	*3.12(6.40)*	*5.2(7.24)*
lnrf_annual	*-40.50*(20.90)*	*-54.83**(23.61)*
lnrf_annual2	*2.85*(1.49)*	*3.86**(1.68)*

**** Significant at 1%, ** Significant at 5%, * Significant at 10%, (s.e)*

Effects of upstream forest cover on water treatment chemical costs

---

[7] *At lower level of rainfall, the effect of rainfall on treatment chemical cost is negative (cost is decreasing due to stronger dilution effect) and at higher level of rainfall, the effect of rainfall on treatment chemical cost is positive (cost is increasing due to stronger soil erosion effect).*

In this section, the forests cover in the upstream area which is our variable of interest. Though our main focus is on the impact of forest cover on aggregate treatment chemical costs, the other explanatory variables have also important implication for the validity of the model employed for the analysis. The effect of the upstream forest cover found to be consistent with prior expectations. It significantly affects the water treatment cost (With increasing upstream forest cover, the treatment cost decreases significantly). This finding is similar with previous studies on the area (Vincent et al, 2016; Ernst 2004; Rahim and Shahwahid , 2011). One exception here is the impact of the treated volume of water on the cost of treatment chemicals, it negatively affects the aggregate chemical cost (at 10% level of significance). Result indicated that the higher the amount of treated water volume, the lower the cost of treatment chemicals. This finding is inconsistent with previous empirical studies in this subject (Vincent et al, 2016). The nature of the data might contribute to this finding.

The other important finding considered is that the impact of annual rainfall on water treatment chemical costs. As expected lower level of rainfall has a cost reducing impact due to what is called stronger dilution effect, and at higher level of rainfall, treatment cost increases by 2.86% with increasing amount of rainfall (significant at 10% level of significance) due to higher soil erosion effect. The rainfall variable takes quadratic form to test these two effects. As expected, rainfall significantly contributes to lower chemical cost at lower levels of rainfall and contributes to increase chemical cost at higher amount of rainfall. The mean annual temperature is not significant both for aggregate chemical costs and for cost of Aluminum Sulphate.

Table 1: Panel fixed effect results in upstream parts of the watershed

Variables	*Panel fixed effect (Dependent : Log of aggregate treatment cost)*	*Panel fixed effect (dependent: log of Aluminum Sulphate cost)*
lnforest_area_upstream	*-5.68***(2.08)*	*-6.982***(2.316)*
Inproduc_tp	*-0.526*(0.268)*	*-.720**(0.298)*
lnaver_tem	*3.64(6.36)*	*5.31(7.09)*
lnrf_annual	*-40.56*(20.88)*	*-54.60**(23.2)*
lnrf_annual2	*2.86*(1.48)*	*3.86**(1.65)*

**** Significant at 1%, ** Significant at 5%, * Significant at 10%*

The impacts of forest cover at different buffer distances

For this particular study, there are about seven different buffer zones. The buffer distance started from 2.5 kilometers and ended at 30 kilometers. The regression result shows that forest cover within the lowest buffer distance has the highest impact on the aggregate chemical cost (13.86%); the forest cover with in the buffer distance of 2.5 kilometers significantly affects the *treatment cost compared to the forest cover found at higher buffer distances. The impact decreases with increasing buffer distance. Table 2 and 3 indicate the regression result from the different buffer distance scenarios. As indicated in table 2 and 3, with increasing buffer distance the impact of the forest cover on both the aggregate chemical cost and Aluminum Sulphate except at forest cover with buffer distance 20 the impact of which is below the next two buffers. This might be due to lower forest cover in the given buffer area. The rho in the last column shows the percentage of the variation explained by water treatment specific effects. Higher magnitude of rho shows robustness of fixed effects since most of the variation is not from idiosyncratic effects.*

Table 2: The impact of forest cover with different buffer distances on aggregate chemical cost

Log of aggregate water treatment cost	**Buffer distances (in km)**						
Independent variables	2.5	5	10	15	20	25	30
Forest cover with in 2.5 km buffer area	-13.86*** (4.62)	-	-	-	-	-	-
Forest cover with in 5 km buffer area	-	-10.53*** (3.27)	-	-	-	-	-
Forest cover with in 10 km buffer area	-	-	-6.687*** (2.4)	-	-	-	-
Forest cover with in 15 km buffer area	-	-	-	-5.43*** (2.07)	-	-	-
Forest cover with in 20 km buffer area	-	-	-	-	-5.689*** (2.08)	-	-
Forest cover with in 25 km buffer area	-	-	-	-	-	-5.684*** (2.08)	-
Forest cover with in 30 km buffer area	-	-	-	-	-	-	-5.684*** (2.08)
Inproduc_tp	-0.30 (0.24)	-0.577 (0.26)	-0.58 (0.28)	-0.51** (0.27)	-0.53** (0.27)	-0.52** (0.26)	-0.53** (0.27)
lnaver_tem	-0.91 (6.64)	1.26 (6.38)	3.92 (6.36)	3.59 (6.40)	3.63 (6.38)	3.63 (6.38)	3.63 (6.38)
lnrf_annual	-50.67** (20.96)	-45.94** (20.61)	-41.94 (20.84)	-40.75* (20.94)	-40.58** (20.89	-40.56** (20.88)	-40.58** (20.89)
lnrf_annual2	3.55** (1.49)	3.24** (1.46)	2.96 (1.48)	2.87* (1.49)	2.86** (1.48)	2.88** (1.48)	2.86** (1.49)
rho	0.99	0.99	0.99	0.99	0.99	0.99	0.99

**** Significant at 1%. ** Significant at 5%, * significant at 10%. (s.e)*

Table 3: The impact of forest cover with different buffer distances on the cost of Aluminum Sulphate

Log of cost to Aluminum Sulphate	**Buffer distances (in km)**						
Independent variables	*2.5*	*5*	*10*	*15*	*20*	*25*	*30*
Forest cover with in 2.5 km buffer area	*-16.08*** (5.16)*	-	-	-	-	-	-
Forest cover with in 5 km buffer area	-	*-13.084*** (3.62*	-	-	-	-	-
Forest cover with in 10 km buffer area	-	-	*-8.68*** (2.65)*	-	-	-	-
Forest cover with in 15 km buffer area	-	-	-	*-6.90*** (2.29)*	-	-	-
Forest cover with in 20 km buffer area	-	-	-	-	*-6.987*** (2.32)*	-	-
Forest cover with in 25 km buffer area	-	-	-	-	-	*-6.982*** (2.316)*	-
Forest cover with in 30 km buffer area	-	-	-	-	-	-	*-6.982*** (2.316)*
Inproduc_tp	*-0.44 (0.26)*	*-0.78 (0.29)*	*-0.82*** (0.30)*	*-0.71** (0.29)*	*-0.721** (0.30)*	*-0.720** (0.30)*	*-0.72** (0.30)*
lnaver_tem	*0.15 (7.41)*	*2.37*** (7.06)*	*5.57 (7.02)*	*5.19 (7.1)*	*5.30 (7.09)*	*5.31 (7.09)*	*5.31 (7.09)*
lnrf_annual	*-66.42 (23.37)*	*-61.26*** (22.81)*	*-56.29** (23.02)*	*-54.78** (23.23)*	*-54.61** (23.22)*	*-54.60** (23.22)*	*-54.60** (23.22)*
lnrf_annual2	*4.67 (1.66)*	*4.33 (1.62)*	*3.98** (1.67)*	*3.87** (1.65*	*3.860** (1.65)*	*3.86** (1.65)*	*3.86** (1.65)*
rho	*0.99*	*0.99*	*0.99*	*0.99*	*0.99*	*0.99*	*0.99*

Conclusion

Quantitative empirical studies on the impact of forest cover on treatment chemical cost is very limited in developing countries like Ethiopia. This study tried to assess the impact of forest cover on water treatment chemical costs using panel data collected from eight water treatment plants and Global Forest cover change dataset during the year 2002 to 2014. The theory of cost function applied to value un-priced environmental inputs that are used for the econometric analysis through taking the cost functions of each water treatment plants. Panel fixed effects regression is used to analyze the effect of forest cover on water treatment chemicals cost at watershed level, upstream forest cover and forest cover with different buffer distances. Aggregate chemical cost to treat water is used as short run operating cost which is comprised of main treatment chemicals. In addition to the aggregate chemical cost, the impacts of forest cover on the cost of one of the treatment chemical (i.e. Aluminum Sulphate) is analyzed.

The finding of this study revealed that with increasing forest cover around water treatments' catchments, the water treatment chemicals cost significantly decreases both for aggregate chemical cost and for the cost of Aluminum Sulphate. The other important finding is that as buffer distance increases, its contribution to the reduction of treatment cost declines while it is still significantly affects the costs to treat water. Therefore, since improved water supply, sanitation and hygiene is one of the targets of the Growth and Transformation Plan (GTP) of Ethiopia and Sustainable Development Goals (SDGs), protecting forests at the source of potable water significantly contributes to water purification and hence reduction of costs to treat water which are incurred due to high turbidity in water.

References

Abdul Rahim AS, Mohd Shahwahid HO (2011) A panel data analysis of timber harvesting operations and its impact on the cost of water treatment. Aust J Basic ApplSci 5:598–601

Alcott E et al (eds) (2013) Natural and engineered solutions for drinking water supplies: lessons from the northeastern United States and directions for global watershed management. CRC Press, Boca Raton

Barten PK, Ernst CE (2004) Land conservation and watershed management for source protection. J Am. Water Works Assoc 96:121–135

Bruijnzeel LA (2004) Hydrological functions of tropical forests. AgricEcosyst Environ 104:185–228.

Chichilnisky G, Heal GM (1998) Economic returns from the biosphere. Nature 391:629–630.

Dearmont D et al (1998) Costs of water treatment due to diminished water quality: a case study in Texas. Water Resour Res 34:849–853

Dudley N, Stolton S (2003). Running pure: the importance of forest protected areas to drinking water. World Bank and WWF, Washington.

Dunne T (1979) Sediment yield and land use in tropical catchments. J Hydrol 42:281–300

Dunne T, Leopold LB (1978) Water in environmental planning. WH Freeman, New York.

Ernest (2004). protecting the source: Land conservation and the future of America's drinkingwater. Water protection series. San Francisco,CA: the trust of Public Landand Americanwaterworker Association online at:http://www.tpl.org/content_documents/protecting thesource_04. .

Ernst, Gullick & Nixon (2004). Protecting the source: Conserving forests to protect water.

FDRE (2012). Ethiopia's Climate Resilient Green Economy: Green Economy Strategy.

Hansen M.C., Potapov P.V., Moore R., Hancher M., Turubanova S.A., Tyukavina A., Thau D., Stehman S.V., Goetz S.J., Loveland T.R., Kommareddy A., Egorov A., Chini L., Justice C.O. & Townshend J.R.G. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. Science, 342, 850-853.

Hanson, Yonavjak, Clark, Minnemeyer, Leach & Boisrobert (2011). Southern forests for the future, Washington DC, World Resource Institute.

Holmes (1988). The offsite impact of soil erosion on the water treatment industry. Land Economics, 64, 56-66.

MEA (2005). Ecosystems and human wellbeing: Synthesis. In. The Millenium Ecosystem Assessment Washington DC, USA.

Moore & McCarl (1987). Off-site costs of soil erosion: a case study in the Willamette Valley. Western Journal of Agricultural Economics, 12, 42-49.

Rahim & Shahwahid (2011). A Panel Data Analysis of Timber Harvesting Operations and Its Impact on the Cost of Water Treatment. Ausralian Journal of Basic and Applied Sciences, 5(12), 598-601.

TEEB (2010). The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendation of TEEB (UNEP, Nairobi).

UNDESA (2014). United Nations Department of Economic and Social Affairs, World Urbanization Prospects, United Nations, New York. In.

Vincent J., Ahmad I., Adnan N., Burwell B., Pattanayak S., Tan_Soo S. & K.Thomas (2016). ValuingWater Purification by Forests: An Analysis of Malaysian Panel Data. Environ Resource Econ 64, 59-80.