INVESTIGATION OF SURFACE WATER RESOURCES AND IMPACT OF WET COFFEE PROCESSING EFFLUENT ON THE WATER QUALITY PARAMETERS OF CHICHU RIVER, SOUTHERN ETHIOPIA

MSc THESIS

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HAWASSA, ETHIOPIA

JUNE, 2019

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THESIS SUBMITTED TO THE DEPARTMENT OF WATER RESOURCE AND IRRIGATION ENGINEERING,
FACULTY OF BIO-SYSTEM AND WATER RESOURCE ENGINEERING,
INSTITUTE OF TECHNOLOGY,
SCHOOL OF GRADUATE STUDIES,
HAWASSA UNIVERSITY,
HAWASSA ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MSc IN WATER RESOURCES ENGINEERING AND MANAGEMENT

JUNE, 2019

APPROVAL SHEET

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

EXAMINERS' APPROVAL SHEET

We the undersigned, members of the Board of Examiners of the final open defense by **Fetene Balese Dinigu** have read and evaluated his thesis entitled "**Investigation of Surface Water Resources and Impact of Wet Coffee Processing Effluent on the Water Quality Parameters of Chichu River, Southern Ethiopia",** and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master's with specialization in Water Resource Engineering and Management.

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DECLARATION AND STATEMENT OF AUTHOR

I hereby declare that this MSc thesis that submitted to Hawassa University, School of graduate studies for the partial fulfillment of the requirements for the degree of Master's with specialization in Water Resource Engineering and Management is my original work and has not been presented for a degree award in any other university, and all sources of material used for this thesis have been duly acknowledged.

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June, 2019

ACKNOWLEDGEMENT

Firstly, I thank Almighty God for giving me strength, compassion, endurance and calm during mysterious time throughout my study and life at whole. “Blessed be God, who has not turned away my prayer, nor his loving kindness from me. Psalms 66:21”

I wish to express my heartfelt sense of gratitude and gratefulness to my advisers, Dr. Abraham W/Michael and Dr. Mihret Dananto for their unreserved guidance and support during my thesis work. I would like to acknowledged ministry of water resources and irrigation of Ethiopia; national meteorological agency of Ethiopia; Ethiopia mapping agency; environmental commission of Ethiopia; environmental protection bureau of SNNPR; Gedeo zone agriculture and natural resource office, and Gedeo zone water and mineral office for their unlimited material support to the my thesis work.

My grateful appreciation is extended to my whole family for their understanding and follows up through the study stay. Exceptional heartfelt thanks go to my dear brother (Nikinake Balese) for his un-tireless effort to help and understand me, my God bless you more!

Sincerely, I would like to admit the contribution of my friends, for their valuable help. And my thanks go to whole school of Water resource and irrigation engineering staff members and office mates for their complement to the completion of my research work. At the end, I would like to confess Dilla University through Ministry of education for the chance of the education.

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LISTS OF ACRONYM AND ABBREVIATION

a.m.s.l	Above Mean Sea Level
AMC	Antecedent Moisture Condition
APHA	American Public Health Association
AWWA	American Water Work Association
BOD	Biological Oxygen Demand
CN	Curve Number
COD	Chemical Oxygen Demand
CSAE	Central Statistical Agency of Ethiopia
DEM	Digital Elevation Model
DO	Dissolved Oxygen
DSP	Downstream Sample Point
EC	Electric Conductivity
ECTDA	Ethiopia Coffee and Tea Development Authority
EEPA	Ethiopian Environmental Protection Agency
ESP	Effluent Sample Point
FAO	Food and Agriculture Organization
GPS	Global Position System
GZANRO	Gedeo Zone Agriculture and Natural Resource Office
HSPF	Hydrologic simulation program FORTRAN
ICO	International Coffee Organization
ITCZ	Inter-Tropical Convergence Zone
Km^2	Square Kilometers
MMC	Million Meter Cube
LULC	Land Use Land Cover
MoWRE	Ministry of Water Resource and Electricity
MWCPPs	Multiple Wet Coffee Processing Plants
NMAE	National Meteorological Agency of Ethiopia
NRCS	Natural Resource Conservation Service

NTU	Nephelometric Turbidity Units
RVLB	Rift Valley Lake Basin
SCS	Soil Conservation Services
SNNPR	South Nation Nationality and Peoples Region
SPSS	Statistical Package for Social Science
SWAT	Soil and Water Assessment Tool
SWAT-CUP	SWAT-Calibration and Uncertainty Program
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UNEP	United Nations Environmental Program
USDA	Untied State Department of the Agriculture
USEPA	Untied State Environmental Protection Agency
USP	Upstream Sample Point
WEAP	Water Evaluation and Planning
WEF	Water Environment Federation
WHO	World Health Organization
WMO	World Meteorological Organization

ABSTRACT

Investigation of surface water resources and its quality were one of the crucial tasks for better planning and management of the scarce resources. Pollution of surface water resource via discharge of industrial effluents is a concern today. Thus, the main objective of study was to investigate surface water resource and impact of wet coffee processing effluents on water quality parameters of Chichu River, Southern Ethiopia. To estimate surface water resource; hydro-meteorological and spatial data were collected and analyzed via SWAT model. To examine water quality parameters; samples were collected from twelve sampling point and analyzed for pH, EC, temperature, turbidity, and DO at onsite level, while TSS, TDS, COD, BOD, $N\text{-}NH^+_4$, $N\text{-}NO_3$, and PO_4^{3-} at laboratory. Result of sensitivity analysis shows; eight parameters were sensitive to the SWAT model. Performance indicators for calibration and validation of the SWAT model shows, good fit of which $R^2=0.69$, NS=0.53 and $R^2=0.71$, NS=0.56 respectively. Since the Chichu River is ungauged, calibrated parameters were transferred from gauged Walame River to estimate water resource. Accordingly, annual surface runoff and total surface water resource corresponds 13.81 and 32.53 Mm^3 respectively. Total water yield is 1066.17 mm, indicates Chichu River catchment has excessive water resource potential. A significant ($p<0.05$) variations were identified in the quality parameters at sampling site and points. Very acidic pH (4.03±0.48); high organic load of which BOD (631.4±71.58), and COD (1960.07±63.5); much deteriorated DO (0.85±0.4); huge nutrient load of which $N\text{-}NH^+_4$ (17.5±0.98), $P\text{-}PO_4^{3-}$(19.67±1.3) and $NO_3\text{-}N$ (17.5±0.6); and very high floating and dissolved materials TSS (4076.87±90.7), TDS (2417.23±25.4), EC (1565.9±62.9 µS/cm), and turbidity (917.43±93.4 NTU) were obtained in the DSP of S4. Except for USP of S1, all studied quality parameters were highly deviated from the surface water quality standards. And during processing period, significant quantity (0.6MMC) of river's available water were directly polluted via releasing of untreated coffee wastewater. In turn, it was found that the downstream water quality were undesirable for drinking, agriculture, and environmental uses during this period. Generally; Chichu River catchment has plenty water resources, but a significant proportion of this water is highly polluted via indiscriminate discharge of effluents from MWCPPs, such that the concerned government bodies and NGOs should develop mechanisms for water resource planning and management.

Keywords: Effluent, Pollution, Chichu River, Regionalization, Water quality parameters.

1. INTRODUCTION

1.1 Background and Justification

Obviously, water is indispensable to all life existence on the earth. The adequacy and availability of the water is an essential measure of this life. Its quality at any point reflects the characteristics of the physiochemical, biological, and ecological conditions. These parameters affect the value of given water and all of which interact with one another to influence the quality of water (Goudey, 2003). In order to assess the quality of water for effective management and utilization, there is the need to study these parameters. Its quality also affected via the availability of the water resource in the system; this mainly connected with natural self-purification capacity of the water bodies from discharged constituents (Loáic & Loáiciga, 2016). As result, water quality and its availability evaluation are one of the important activities of human being to protect its life and to manage this resources in the sustainable manner to safeguard it for current and future generation (USEPA, 2011).

Assessment of surface water resource is vital for planning and development of the water resource management projects (Awulachew *et al*., 2007). For estimating surface water of the catchment different hydrologic model may be used, these models required measured stream flow data for calibration and validation of the model result (Abbaspour, 2015). Since the Chichu River is ungauged rivers in the Rift valley lake basins of Ethiopia, estimating water resource through hydrologic model poses problem. However to overcome this difficulty, estimation of the water resource in the ungauged river were possible through regionalization techniques (Abimbola *et al*., 2017; Mbungu & Kashaigili, 2017). This techniques performed by transferring calibrated model parameters from comparable gauged catchments (Ammar *et al*, 2017) to ungauged catchments based on the similarity of the hydro-meteorological, physical, and hydrologic response unit characteristics of the donor and receipt catchments. Which performed by using physical based and continuous hydrologic model (Neitsh *et al*., 2012), soil and water assessment tool via transferring calibrated model parameters from gauged river. But, the surface water resource potential of the Chichu River catchment was not estimated before. Thus, transferring calibrated model parameters based on hydrologic response unit similarity of catchments is vital to estimate water resource in ungauged river.

Fresh water resource especially surface water pollution by several contaminants all over the world considered as an epidemic problem and its quality affected by the influences of natural and anthropogenic activities. Industrial process stayed one of the anthropogenic activities that directly affect the quality of water (Zhang *et al*., 2010). Agro-industries are one of them and coffee processing stations are prominent. Global annual production of the coffee is estimated to 8.1 million tons, and over 90% of productions take place in developing countries (USDA, 2011). Ethiopia is one of the coffee producing countries and origin of the coffee plant. It processed via wet and dry methods, the wet coffee processing method is widely practiced, in which the coffee berry is subjected to mechanical and biological operation to separate the bean from skin, mucilaginous pulp and parchment (Dejene *et al*., 2015; Blinová *et al*., 2017). According to the Ethiopia coffee and tea development authority (ECTDA) the countries' the total number of the coffee processing mills were 2156 of which 1249 and 907 are wet and dry coffee processing mills respectively (ECTDA, 2017). Recently emphasis was given to produce quality coffee via WCP methods, but in this process a massive amount of pulp effluent was generated and poses problem of disposal.

In Chichu River following the course of river nineteen wet coffee processing mills were planted (GZANRO, 2019). Since it requires a lot of water, almost all of the plants were located proximate to river and produces coffee wastewater, mucilage and coffee pulp as by-products. And also, almost all wet mills in Ethiopia are not re-using the water after once used for pulping and fermentation. As result of this, all the generated effluent is directly discharged to the downstream water bodies without any treatment (Minuta & Jini, 2017). Such unsafe way of the wastewater disposal had great effect on terrestrial and aquatic ecosystem and becoming an evolving environmental problem worldwide due to its rapid decomposition and constitutes a source of severe contamination (Blinová *et al*., 2017). Moreover, using multiple WCP mills on same river; result in aggravated downstream water quality deterioration and serious pollution due to releasing of huge wastewater with organic, inorganic, biological and physical constituents. And, as it uses large amount of the quality water and produce enormous wastewater in turn made trouble in managing. So that the site specific study were vital to overcome stated problem through understanding the characteristics of coffee wastewater for designing appropriate treatment technologies and to evaluate the suitability of downstream water quality via assessing of the selected water quality parameters. Therefore, this study focused on the investigating the surface water resource and impacts of the coffee wastewater that discharged from multiple wet coffee processing plants on the water quality parameters of the Chichu River.

1.2 Statement of the Problem

In coffee producing countries; the wastewater that released from wet coffee processing mills presents serious problem on receiving environment (USEPA, 2011). Some existing studies; by using different river for evaluation shows wet coffee processing plants result in the polluting the downstream water resources due to releasing of untreated coffee wastewater (Woldesenbet *et al*., 2014; Dejene *et al*., 2015; Alemayehu, 2016; Minuta & Jini, 2017; Dessalegn, 2018). In addition, Chichu River catchment locates numerous processing mills and generated effluents were directly released to river water, this result in adversing the health of neighbor pupils and quality of river water. However, the study that evaluates the impact of effluent from multiple wet coffee processing mills on the same river was not done before.

Estimating surface water resource at catchment level is crucial for effective planning and management. The scanty of the hydrologic and meteorological data for this catchment stayed as problem, due to ungauged river. By using regionalization technique transferring parameters from proximate and comparable gauged river was possible to overcome this difficulty. But, for the catchment there is no studies previously show water resource potential of the catchment. In addition, the suitability of the downstream water for different beneficial uses based on its quality and available standards was not evaluated earlier.

Therefore, studying the water resource of the catchment via transferring calibrated parameters from gauged river is useful to estimate surface water potential, is vital for planning and development of the water resource management project at catchment level. And assessing water quality parameters at catchment level is important to understand the nature and characteristics of coffee wastewater for the appraisal of the treatment technologies; and to evaluate the suitability of the downstream water for different beneficial uses.

1.3 Objectives of the study

1.3.1 General objective

The overall objective of this study is to investigate surface water resource and impact of effluent discharge from wet coffee processing plants on water quality parameters of Chichu River, Southern Ethiopia.

1.3.2 Specific objectives

- To estimate surface water resource potential of the catchment
- To assess the impact of wet coffee processing effluent on selected water quality parameters
- To evaluate the quantity of surface water that directly polluted
- To evaluate the suitability of the downstream water quality for beneficial uses

1.4 Basic research questions

- ➢ How much is surface water resource in the catchment?
- ➢ How much surface water is polluted directly via releasing effluents?
- ➢ At what level the coffee effluent impact selected quality parameters of the river water?
- ➢ Is downstream water suitable for different uses based on the quality?

1.5 Significance of the study

This study focused on assessing surface water resource and effect of the coffee wastewater on the water quality of Chichu River based on the selected physiochemical parameters. As calibrated model parameters transferred to ungauged Chichu catchment, surface water resource potential of the river was estimated. This is vital for planning and development of the water resource management projects and for easy data access. Through characterization, level of the impact evaluated via comparing the result of this study with available standards. And also, appropriate technology for treating coffee wastewater was set forth and the amount of the directly polluted water via releasing of effluents was studied, this important to know quantity of the available and polluted water during processing period. Furthermore, as downstream water examined for its quality based on selected quality parameters and available standards; their suitability for drinking, agriculture and environmental uses was checked.

1.6 Scope of the study

Off course, assessment of the water resource potential incorporates both surface and groundwater of the catchment, however this study estimate the surface water resource of the catchment by using soil and water assessment tool. Water quality at any point affected by natural and anthropogenic factors, but evaluating overall quality parameters limited in this study. Thus, the range of this study for water quality assessment focused on twelve selected physiochemical and nutrient parameters (pH, temperature, total suspended solids, total dissolved solids, turbidity, electric conductivity, dissolved oxygen, chemical oxygen demand, biological oxygen demand, phosphate, ammonia and nitrate).

In addition, examining the suitability of the downstream river water may incorporate many quality parameters for different beneficial requirements (agriculture, drinking, industrial, and environmental uses); but in this study the suitability was evaluated based on the above described quality parameters and respective quality standards for domestic, agriculture and environmental uses.

2. LITERATURE REVIEW

2.1 Surface Water Resources Assessment

Ethiopia is endowed with a vast quantity of the water and the total annual flow from all rivers estimated to be 122 billion cubic meter. The country has 12 river basins, 11 fresh and 9 saline lakes, 4 crater lakes and more than 12 major swaps (MoWRE, 2012). The Rift Valley Lake basin incorporates an area of 52,739 km^2 and it is a location for major natural and artificial lakes with its surface area estimated to be 7,500 km^2 (Awulachew *et al*., 2007). But very little water resources have been developed for agriculture, industry, hydropower, water supply and other purposes (MoWRE, 2012). The availability and use of water mainly controlled by its spatial distribution in quantity and its quality affected via influence of the natural and anthropogenic factors. Thus water resource management is one of the challenges the world face today, in order to meet the demand of different uses without compromising the quality and integrity of the ecological conditions (Pontes *et al*., 2016).

Surface water is water that is open to the atmosphere and fed by runoff from the surface, such as in a stream, river, lake, or reservoir. Water discharged into a river is the runoff from the watershed drained by the river (Gebremeskel, 2005). It is a valuable resource that can be used for public, industrial, navigation and agricultural supply purposes, etc. Freshwater resources in the Chichu River catchment are particularly used for domestic, industrial and agricultural purposes. As noted in the Tadesse *et al*., (2015), increased agricultural water demand, expanding of the industrial activity, population growth, the disparity of rainfall distribution make production of sufficient food and to contribute the ecological sustainability on flow, are going to greatly worsen.

Therefore, understanding surface water resources potential and quality is a key aspect of water resource assessment, evaluation and development and also crucial in order to plan for the future and make wise decisions. The assessment of water availability at catchment level is realized by quantifying runoff generated in the watershed. According to the Abbaspour *et al*., (2017) water resources assessment relies on a full understanding of all the water flows and storages in the river basin or catchment under consideration, different studies carried out at global and national level about water resources assessment in watershed and basin level. But the study to assess water resource potential of the Chichu River catchment was unavailable before. Thus, present research is focusing on catchment level to assess their water resources availability in detailed.

2.1.1 Water resources assessment models

Several hydrologic models are widely used for the assessment of the water resource. Hydrological models are characterizations of the real world system. Rainfall runoff models have broadly used in hydrology over the last century for a number of applications, and play an important role in optimal planning and management of water resources in catchments (Mohammad, 2016). But, the needed rainfall runoff processes of hydrology is being limited due to different reasons including; restricted range of the hydrological measurement and limited range of measurements in space and time (Pontes *et al*., 2016). They reported that the main challenge associated with applying successfully rainfall-runoff model lies in the lack of monitoring data, mainly rainfall spatial distribution over the catchment area, since rainfall is the primary input in any hydrological model. Another potential problem is having no reliable flow data that can lead to reliable calibration and validation of catchment parameters (Perera, 2009).

These models are classified as physical based, conceptual and empirical depending on the degree of complexity and physical competences in the formation of the structure. Models are further classified as lumped, semi-distributed and distributed depending on the degree of decentralization when describing the terrain in the basin. Most rainfall runoff models, whether physical or conceptual are distributed to some degree and larger basins are split into sub basins (Neitsh *et al*., 2012; Ammar *et al*., 2017).

2.1.1.1 Soil and water assessment tool

The Soil and Water Assessment Tool (SWAT) model (Arnold *et al*., 2011; Inchell *et al.*, 2013) is a physically-based continuous-time, conceptual, long-term, distributed watershed scale hydrologic Model developed by USDA’s Agricultural Research Service designed to predict the impact of land management practices on the hydrology, sediment and contaminant transport in large, complex catchment.

SWAT is physical based model and allows different physical process to be simulated; it requires specific information about weather, soil properties, and topography, vegetation and land management practices occurring in the watershed. Its application was increasing in past few decades due to; capability to simulate physical process associated with water and sediment movement, crop growth, nutrient cycling, etc are directly modeled by using this input, this approach important for the watershed with no monitoring data (Derib, 2013), It has capabilities of simulating surface runoff, percolation, return flow, erosion, nutrient loading, pesticide fate and transport, irrigation, groundwater flow, channel transmission losses, pond and reservoir storage, channel routing, field drainage, plant water use and other supporting processes from small, medium and large watersheds. It can be applied to a large ungauged rural watershed with more than hundred numbers of sub watersheds (Fereidoon *et al*., 2018).

For this reason, SWAT is increasingly being used to support decisions about alternative water management policies in the areas of land use change, climate change, water re-arrangement, and pollution control. There are numerous applications of SWAT model all over the world (Neitsh *et al*., 2012). Out of the mentioned hydrologic models SWAT model can simulate all of the components of land phase of hydrologic cycle.

SWAT is a process-based and time continuous hydrological model operating at a daily scale. The model is semi-distributed and allows simulation of a high level of spatial detail by dividing the basin into a large number of sub-basins and hydrologic response units (Arnold *et al.*, 2012). The soil water balance equation is the basis of hydrological modeling. The simulated processes include surface runoff, infiltration, evaporation, plant water uptake, lateral flow and percolation to shallow and deep aquifers (Vilaysane *et al*., 2015).

For modeling purposes, a watershed may be partitioned into a number of sub basins. The uses of the sub basins in the simulation beneficial; when different areas of the watershed are dominated by land use/soils dissimilar enough in properties to impact hydrology; the user is able to reference different areas of the watershed to one another spatially. Input information for each sub basin is grouped into climate, hydrologic response unit (HRU), ponds, groundwater, and the main channel. HUR are lumped land areas within the sub basin that are comprised of unique land use, soil, and management combinations. The subdivision of the watershed enables the models to reflect differences in evapotranspiration for various crops and soils. Stream flow is predicated separately for each HRU and routed to obtain the total runoff for the watershed (Pignotti *et al*., 2017).

Simulation of the hydrology of the watershed separated into two major divisions; Land phase of the hydrologic cycle; controls the amount of the water, sediment, and nutrient and pesticide loadings to the main channel in the each sub basin. And water/routing phase of the hydrologic cycle can be defined as, the movement of the water, sediments, etc. via the channel network of the watershed to the outlet (Neitsh *et al*., 2012).

2.1.1.2 Water Evaluation and Planning tool

Water evaluation and planning tool (WEAP), which is an object-oriented computer-modeling package, having is an integrated water resources management tool designed for simulation of water resources systems and trade-off analysis. The model simulates water system operations within a river system with basic principles of water accounting on a user-defined time step, usually a month. Simulation allows the prediction and evaluation of what if scenarios and water policies such as water conservation programs, demand projections, hydrologic changes, new infrastructure and changes in allocations or operations priority (Fereidoon *et al*., 2018). WEAP model is developed by the Stockholm Environment Institute (SEI) in Boston and provides an integrated approach to simulating water systems associated with development (SEI, 2007).

According to SEI, 2007 the model includes two separate systems simulation of natural hydrological processes (e.g., evapotranspiration, runoff and infiltration) to enable assessment of the availability of water within a watershed; and simulation of anthropogenic activities superimposed on the natural system to influence water resources and their allocation (i.e., consumptive and non-consumptive water demands) to enable evaluation of the impact of human water use.

The model performs a mass balance of flow sequentially down a river system, making allowance for abstractions and inflows. Typically, the model applied by configuring the system to simulate a recent baseline year, for which the water availability and demands can be confidently determined. The model is then used to simulate alternative scenarios (i.e., possible futures based on what if propositions) to assess the impact of different development and management options (Tena, *et al*., 2016).

2.1.1.3 Hydrologic simulation program in FORTRAN

Hydrologic simulation program FORTRAN (HSPF) includes components that predict runoff and water quality constituents on land areas, movement of water and constituents in stream channels and mixed reservoirs. The model is part of the United States Environmental Protection Agency (USEPA) BASINS modelling systems with user interface and ArcViewGIS platform (Inchel *et al*., 2014). The application of HSPF to a catchment requires physical data (topographic, land use) and climate data (precipitation, temperature, average wind speed, average humidity, average solar radiation, daily potential evaporation (Chung & Lee, 2009). The model was applied in number of studies to simulate water quantity and water quality with varying degrees of success. HSPF reproduced monthly runoff with correlation coefficients ranging from 0.87 to 0.89 during the calibration (Fereidoon *et al*., 2018). Statistical evaluation of HSPF model gave Nash-Sutcliffe efficiency coefficient ranging between 0.70 and 0.84 for daily and monthly calibration period respectively, and ranging between 0.84 and 0.86 for daily and monthly validation period respectively, as reported by Nash *et al*., (2012)

2.1.2. Water resource assessment tools selection criteria

To select right hydrologic model based objectives of the study numerous criteria are used, in which they are project dependent and has its own specific requirements and needs. Additional, some criteria are user depended, such as personal preference for graphical user interface, computer operation system, input/output management and structure, or users add on expansibility (Inchell *et al*., 2013). For selecting appropriate model for catchment; spatial scale and physical detail of the models are important to know the determination of the model behaviors as required data, expected accuracy and user friendliness; required model outputs; hydrologic processes that need to be modeled to estimate the desired outputs adequately; availability of input data and price. Based on these descriptions SWAT model was selected as tool for estimating surface water resource of the ungauged Chichu River.

2.1.3 Regionalization techniques for data poor catchment

Regionalization can be described as grouping basins into homogeneous regions. The resulting regions were assumed to be homogeneous in terms of hydrologic responses. In the recent study homogeneity implies that region has similar runoff generating mechanisms. Many regionalization studies concluded that such a region must be geographically continuous. Regionalization can be depending on geographical proximity, climatic and physiographic characteristics of the catchment.

The use of hydrologic models for un-gauged catchments becomes important issues in hydrological study. Regionalization study aimed to estimate parameter values of hydrological models for sub-catchments or large geographic regions. Regionalization methods aim to relate catchment characteristics and geographical location with model parameters (Kerimi, 2017).

Model selection is determined by the availability of data, purpose of application and the accuracy of the output needed. Physically based distributed models need more data to calibrate a watershed. However, they are good for ungauged watersheds, effectively saving time for measuring every parameter of the watershed once they are calibrated. Studies advise to take care when using these models for data-scarce areas (Getachew & Kim, 2015).

2.2 Water Quality and its Parameters

Water quality is described on the basis of the physical, chemical, biological and bacteriological characteristics. Its quality criteria linked to water uses and ecological impacts that determine the relevance of the characteristics describing the water quality (Aisha *et al*., 2013). For practical reasons, the number of characteristics is limited to core parameters when assessing water quality for a particular use, or in relation to ecological quality (Mihert, 2016). These parameters are often defined on the basis of quality standards and criteria such as the maximum allowable concentrations of a pollutant in water may vary in time and location (Islam *et al*., 2016). For statistical expressions and interpretations of the water quality data for purposes of evaluating the level of quality and for its monitoring; sampling and analysis was vital. According to the Ulloa *et al*., (2012), in principle the quantitative values of water quality parameters should never be recorded without details about their statistical characteristics (mean, variance etc.) or characteristics of the time series and the sampling or analysis method level of accuracy. Its standard is a limit value for a specific parameter which may only be exceeded incidentally, if at all.

2.2.1 Surface water quality and its pollution

From surface water system, river is a system which includes the main course and its streams. It is responsible in carrying the load of dissolved and particulate phases from both natural and anthropogenic sources along with other contents. This substance moves downstream and will be experiencing chemical and biological changes (Tadesse *et al*., 2018).

Even Ethiopia is endowed with major surface water resources, but it has suffered from a lack of access to safe drinking water from improved sources (Sisay *et al*., 2017). According to the Dagnew *et al*., (2010) this linked with mismanagement and intentionally discharging of the waste from industrial process and potential of the receiving water bodies to dilute the discharged wastes. A high level of pollutants in river water systems causes such water unsuitable for drinking, irrigation, and for other domestic purposes. In order to ensure a safe public health, water supply for human consumption from such sources must be free from pathogens, chemical toxins and must be physically clear and appealing to taste (Sperling, 2007).

2.2.2. Sources of water pollution

Pollution of water is defined as any physical, chemical or biological change in water quality which adversely impact the living organisms in the environment or which makes a water resource unsuitable for one or more of its beneficial uses (Le *et al*., 2012). The reason for its high level of pollution is that, water is indeed a wonderful chemical medium which has unique properties of dissolving and carrying in suspension huge varieties of chemicals. Thus it can get contaminated easily which shows that, much of water pollution is due to anthropogenic activities (Samuel *et al.*, 2007). Generally, water pollution is caused by the presence of some organic, inorganic, biological, radiological, or physical foreign substances in the water with high concentrations than allowable limits that tend to degrade its quality. The presence of undesirable and hazardous materials and pathogens beyond certain limit will also cause water pollution (Helmer *et al*., 1997).

Water pollution due to discharge of untreated industrial effluents into water bodies is a major problem in the global context. The problem of water pollution is being experienced in both developing and developed countries (UNEP, 2006). Human activities give rise to water pollution by introducing various categories of substances or waste into a water body. The more common types of polluting substances include pathogenic organisms, oxygen demanding organic substances, plant nutrients that stimulate algal blooms, inorganic and organic toxic substances (EEPA, 1997).

According to WHO/UNICEF, (2015) globally almost nine hundred million people lack access to safe drinking water, as result of water quality deterioration through changes in nutrients, sedimentation, temperature, pH, heavy metals, non-metallic toxins, persistent organics, pesticides, and biological factors; among many other factors. The discharge of industrial effluent into water bodies is one of the main causes of environmental pollution in many cities, especially in developing countries. Many of these industries lack liquid and solid waste regulations and proper disposal facilities, including for harmful waste (Troyer *et al*., 2016). Increasing numbers and amounts of industrial, agricultural and commercial chemicals discharged into the aquatic environment have led to various deleterious effects on aquatic organisms (Samuel *et al*., 2007).

Aquatic organisms affected by the accumulated pollutants that directly discharged from contaminated water and indirectly via the food chain. The pollutants are usually pathogens, silt and suspended solid particles such as soils, sewage materials, disposed foods, cosmetics, automobile emissions, construction debris and eroded banks from rivers and other waterways (Ali *et al.*, 2011). Industrial activities are frequently associated with prior water pollution caused by disposal of generated waste from their operation and processing. Depending on the industry and their water use, the wastewater contain suspended solids, both degradable and non-biodegradable organics, oils and greases, heavy metal ions, dissolved in organics, acids, bases, and coloring compounds (Asrat, 2015; Kassahun, 2008).

2.2.3. Effects of agro-based industries on river water pollution

Pollution of water and its environment may occur as result of different agro-based activities. Coffee processing plants are one of the major agro-based industries which are responsible for water pollution. Coffee is one of the world's largest agricultural products and it is one of the most popular beverages, which consumed by millions of people every day. It is the second largest traded commodity in the world after petroleum, and generates huge amount of coffee by-products during processing (Dessalegn, 2018). According to U.S. Department of Agriculture (USDA) the world's coffee production reached 8.1 million tons in 2011 and over 90% of coffee production takes place in developing countries, while consumption is mainly in the industrialized economies (USDA, 2011). In many coffees processing countries the wastewater is disposed from pulping, fermentation, washing of coffee beans and presents series of problem on receiving environment especially on water bodies (Padmapriya *et al*. ,2013).

2.2.4. Coffee production and its processing in Ethiopia

Coffee is a major crop grown worldwide and is one of the most popular beverages consumed through the world. Ethiopia had been the origin of coffee because coffee plant initially was found and cultivated in the Kafa province (Asrat *et al*., 2015). It is slightly acidic and can have a stimulating effect on humans because of its caffeine content. Coffee is distributed with different species including; Coffea Arabica, Coffea Robusta, and Coffea Liberica. Arabica coffee usually receives a premium for its superior flavor and aroma-Arabica is more suited to higher elevation and cooler climate 600 to 2300m above sea level and 15 to 20 ^{0}C respectively (Kassahun, 2008).

In Ethiopia, coffee plays a central role in the incomes of more than million coffee-growing households and the livelihood of over 15 million people directly or indirectly depends on this commodity crop. It provides employment for a quarter of the population and contributes up to 50% of household income. Nineteen-five percent of the coffee production in the country is covered by smallholder farmers with land holding size of less than two ha (ICO, 2015) According to the ECTDA, the total number of coffee processing plants in Ethiopia are 2156 of which 1249 and 907 were wet and dry coffee processing plants (ECTDA, 2017). Depending on the crops geographical and climatic requirements most of processing mills were found in Oromia and Southern region of the country. Thus, southern region incorporates 920 mills of which 695 and 225 were wet and dry respectively. From this grand total of the region as Gedeo zone well known for producing coffee for national and international markets; a total of 255 coffee processing plants of which 183 and 72 wet and dry located respectively.

Almost all wet coffee processing plants in Ethiopia are located close to water bodies as result of it require a lot of water, on average 147 m^3 per day required for coffee processing, which is needed for washing the beans, removing the pulp and the mucilage, but also in order to use the water bodies for direct disposal of the wastewater released from the wet coffee processing plants (Dejene *et al.*, 2015; Ulsido & Li, 2016) In Ethiopia almost all, wet coffee processing industries are not reusing the water, which is once used for pulping and fermentation. Thus, all the generated wastewater is directly released to downstream water bodies, and sometimes in disposal pits (Padmapriya *et al*., 2013). While there are some wet coffee processing plants that use disposal pits to stabilize the generated wastewater, these disposal pits are constructed without following the correct design and dimensions. In addition, they lack the proper linings to protect against leakage of the effluents into the underground water and the holding capacity of the disposal pits is not taken into consideration during construction. Thus, the coffee processing water and its wastewater are routinely discharged into nearby streams and rivers (Asrat *et al*., 2015).

2.2.4.1. Wet coffee processing method

Wet coffee processing is widely accepted for selection of ripe coffee fruit which is essential for producing good quality coffee beans. Almost half of the world coffee harvest is processed by wet method in which the coffee berry is subjected to mechanical and biological operation in order to separate the bean seed from the outer red skin, white flesh pulp, and the endocarp (ICO, 2015). It discards away 99% of the biomass generated by the coffee plants at different stages. This includes cherry wastes, parchment (produced when washed coffee is dried), sliver skin, coffee spent grounds, coffee leaves, coffee pulp and wastewater. As cited by Blinová *et al*., (2017), organic waste products such as mucilage (thick and gluey substance which is removed from coffee bean during wet coffee pulping and fermentation processes) and pulp represent a major source of environmental pollution and their disposal is usually done in the water resources closest to the processing sites, such as rivers and lakes. Pulp and mucilage consume the oxygen in water, resulting in the death of plants and animals due to the lack of oxygen or the increased acidity (Dhananjaya *et al.*, 2009).

Wet coffee processing step yields coffee pulp, mucilage, enormous quantities of high strength wastewater on the one hand, and coffee beans with hulls on the other. The separated pulp which is used for varieties of purposes can be discarded as waste material after which the grains are transported to fermentation reservoirs. In the fermentation reservoirs the grains remain between 12 and 36 hours, depending on the temperature, the thickness of the mucilage layer and the concentration of enzymes. Then, mucilage layer is fermented through a combination of microbial activity and the work of endogenous enzymes contained within the mucilage (ICO, 2015). The process is finished after the grains are washed to eliminate the last remnants of decomposed mucilage. Finally, coffee brought to mill is to be sun dried. When it is dried the parchment is manually or mechanically removed (Marsolek *et al*., 2012).

2.2.4.2. Dry coffee processing method

In dry method, the coffee cherries are dried immediately after harvest by letting in the open field to be sun dried. After the cherries have lost almost all their water content, then are grinded or hulled to eliminate the dehydrated mucilage, the pectin, the pericarp and the parchment (Kiran *et al,* 2018). This can be done by hand using a pestle and mortar or in a mechanical huller. The mechanical hullers usually consists of a steel screw, the pitch, of which increases as it approaches outlet so removing the pericarp (Blinová *et al*., 2017).

2.2.5. Characteristics of coffee effluents and water quality parameters

Wet coffee processing effluents are complex mixtures of physicochemical, organic, and biological composition and it may vary depending on coffee diversity (Chanakya & Alwis, 2004). Calvert, (2010) noted that, the effluent from wet coffee processing plants are highly colored, acidic and contain non-biodegradable compounds, and are high in biological and chemical oxygen demand. Coffee wastewater had high concentrations of suspended solids, dissolved solids and elevated nutrient. Moreover, it usually has high amount of conductivity, lower dissolved oxygen and elevated amount of turbidity to nearby water bodies.

The characteristic features of coffee wastewater exhibits the physical, chemical, biological and nutrient characteristics. Physical features include color, odor, temperature, electrical conductivity, and turbidity, suspended and dissolved solids. Chemical parameters are associated with the organic content of wastewater include the chemical and biochemical oxygen demand, total organic carbon. And nutrient parameters mainly include phosphate, nitrogen as nitrate and ammonium (Tadesse & Alemayehu, 2016). Physicochemical parameters of water are necessary to assure that water is safe for its beneficial uses and to monitor the various water treatments for safe water supply (Kiran *et al,* 2018).

2.2.5.1 Water temperature

Temperature of water is a very important physical parameter to assess thermal pollution and associated effects of the aquatic life for their growth and reproduction. Its abnormal level alters chemical reactions rate and solubility of gases (Kassahun, 2008). According to the Yalçın *et al,* (2005), a sudden change in a temperature of river water can lead to a higher rate of mortality of aquatic biota and affects the speed of chemical reactions, the rate at which algae and aquatic plants photosynthesis, the metabolic rate of other organisms, as well as how pollutants, parasites, and other pathogens interact with aquatic residents. It is important in aquatic systems because it can influence the solubility of dissolved oxygen and other materials in the water column (e.g., ammonia). In general the temperature has an effect on most chemical reactions that occur in natural water systems and it also has pronounced effect on the solubility of gases in water (USEPA, 2011).

2.2.5.2. Electrical conductivity

Conductivity is the ability of a substance to conduct electricity. The conductivity of water is a more-or-less linear function of the concentration of dissolved ions. It related water to total concentration, concentrations of the dissolved substances, and their ions in the water, their valence charge and mobility. If the conductivity of a river or a stream suddenly increases, it indicates there is a source of dissolved ions in the neighborhood. Therefore, conductance can be used to detect pollution sources (Sperling, 2007).

According to APHA, (1999), conductivity measurements can be used as a quick way to locate potential water quality problems. Thus changes in conductivity of water sample may show signal changes in mineral composition of water, seasonal variation in reservoirs, and pollution of water from industrial wastes.

2.2.5.3. Turbidity

Turbidity refers to water clarity and it related to the scattering of light by fine and suspended particles that cause water to have a cloudy appearance. Turbidity is mainly caused by suspended matter or impurities and the major source in the open water zone of most rivers are typically clays and silts from soil erosion, re-suspended bottom sediments, finely divided organic and inorganic matter, building and road construction, urban runoff, decaying plants, industrial wastes, and organic detritus from stream and/or water discharges (Goudey, 2003). It mainly used to indicate water quality and filtration effectiveness. Elevated concentrations of solids affect the clarity of the water (UNEP, 2006). Turbidity affects fish and aquatic life by interference with sunlight penetration. If suspended particles block out light, photosynthesis and the production of oxygen for fish and aquatic life will be reduced. Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria (APHA, 1999). Nephelometric Turbidity Units (NTU) and Visual methods – Jackson Turbidity Units (JTU) are two widely used methods for determination of turbidity. And also it easily measured by using Turbidity meter. This meter is graduated at 30 to 1500 NTU.

2.2.5.4. Dissolved oxygen

Dissolved oxygen (DO) levels in natural waters and wastewaters depend on the physical, chemical and biochemical activities in the water body. For example, dissolved oxygen decreased due to increase in temperature and microbial activity. The analysis for DO is a key test in water pollution and waste treatment process control (Patil *et al*., 2012). There are different methods for the DO analysis based on the inferences present, the accuracy desired, and in some cases, convenience or expedience. Winkler or Iodometric method is a titrimetric procedure based on the oxidizing property of DO and Electrometric method using membrane electrodes is the procedure based on the rate of diffusion of molecular oxygen across a membrane. Alternatively DO content of the water and wastewater may be measured using DO meter, which is easy way for assessment at field level (APHA, 1999)

2.2.5.5. Biological oxygen demand

BOD is a measure of the oxygen used by microorganisms to decompose the waste material. Microorganisms such as bacteria are responsible for decomposing organic waste. When organic matter such as dead plants, leaves, manure, sewage, and other organic waste is present in water, the bacteria will begin the process of breaking down this waste. When this happens, much of the available dissolved oxygen is consumed by aerobic bacteria, robbing other aquatic organisms of the oxygen they need to live (Kwak *et al*., 2013). According to the Akpen *et al*., (2016), it also measures the amount of oxygen utilized by micro-organisms during the oxidation of organic materials. It gives an indication of water pollution potential of a given organic waste. The test has its widest application in measuring waste loading to treatment plants and in evaluating the efficiency of such treatment systems.

The determination of BOD used to determine the relative oxygen requirements of wastewaters and one of most common parameters to assess the quality of the surface water and waste load of the treatment plants. The test measures the oxygen required for the biochemical degradation of organic material (carbonaceous demand) and the oxygen used to oxidize inorganic material such as sulfides and ferrous iron. It also may measure the oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand) unless their oxidation is prevented by an inhibitor (Calvert, 2010).

The wastewater that emanated from the wet coffee processing mills has high organic contents, which facilitate microorganism action to degrade dissolved oxygen contents. When the wastewater with high organic contents discharged to the nearby river water may deteriorate the dissolved oxygen contents of the water. But the wastewater with high organic matter content may be used as compost and energy source for the better management of the coffee wastewater (Ulsido & Li, 2016). As noted in the Ramya *et al*., (2015), care must be taken to ensure proper biological activity during the BOD test, thus a wastewater sample must be free of chlorine. If the microbial population is inadequate or unknown, a "seed" solution of bacteria is added along with an essential nutrient buffer solution that ensures bacteria population vitality.

2.2.5.6. Chemical oxygen demand

The chemical oxygen demand (COD) determination is widely used in municipal and industrial organic contamination in wastewater to measure the overall level of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. The contamination level is determined by measuring the equivalent amount of oxygen required to oxidize organic matter in the sample (APHA, 1999).

COD differs from BOD in that it measures the oxygen demand to digest all organic content, not just that portion which could be consumed by biological processes. The test is useful for monitoring and control after correlation has been established. For testing COD; Open Reflux, Closed Reflux, Titrimetric and Colorimetric were widely used method (Blinová *et al*, 2017).

2.2.5.7. Total suspended solids

Solids refer to matter suspended or dissolved in water or wastewater and it may affect water quality in different ways. TSS includes all particles suspended in water, which will not pass through a filter. Suspended solids are present in sanitary wastewater and in many types of industrial wastewater. There are also nonpoint sources of suspended solids, such as soil erosion from agricultural and construction sites (WHO, 2004). Suspended particulate matters in natural water bodies reduce clarity and contribute to a decrease in photosynthesis, act as binding sites for toxic substances and lead to increase water temperature through the absorption of sunlight. Waters with high suspended solids may be esthetically unsatisfactory for such purposes as domestic, agriculture, and for other beneficial uses (Padmapriya *et al*., 2013).

2.2.5.8. Total dissolved solids

Total dissolved solids (TDS) are differentiated from total suspended solids (TSS), in that the latter cannot pass through a sieve of two micrometers and yet are indefinitely suspended in solution. TDS in water originate from natural sources, sewage, urban runoff, and industrial wastewater. These solids include inorganic salts, principally calcium, magnesium, potassium, sodium, bicarbonate, chlorides, sulphates, and small amounts of organic matter that are dissolved in water (USEPA, 2015). Waters with high dissolved solids generally are of inferior palatability and may induce an unfavorable physiological reaction in the transient consumer. The coffee wastewater from wet coffee processing mills contains huge amount of the TDS, this much contents discharge into the nearby river water and raise the level of the dissolved solids in water bodies (Ulsido & Li, 2016). For these reasons, a limit of 500 and 1000 mg dissolved solids per liter is desirable for drinking waters and surface water quality respectively. Highly mineralized waters also are unsuitable for many industrial applications (WHO, 2017). According to Viswanathan, (2015), discharge of wastewater with a high TDS level would have adverse impact on aquatic life, render the receiving water unfit for drinking and domestic purposes, reduce crop yield if used for irrigation, increase conductivity, and exacerbate corrosion in water networks. The presence of high levels of TDS in drinking water may be objectionable (WHO, 2017).

2.2.5.9. pH

The measurement of pH is one of the most important and frequently used tests in water quality assessment study. Practically, every phase of water supply and wastewater treatment is pH dependent. Its value is the logarithm of reciprocal of hydrogen ion activity in moles per liter. In water solution, variations in pH value from 7 are mainly due to hydrolysis of salts of strong bases and weak acids or vice versa (APHA, 1999). The overall pH value range of natural water is generally between 6 and 8. Industrial wastes may be strongly acidic or basic and their effect on pH value of receiving water depends on the buffering capacity of water. The pH value of water obtained in the laboratory may not be the same as that the time of collection of water samples, due to loss or absorption of gases, reactions with sediments, hydrolysis and oxidation or reduction taking place within the same sample bottle. PH value should preferably be determined at the time of collection of sample/onsite determination is preferred (USEPA, 2011).

According to the USEPA, (2011), the relative proportion of hydrogen and hydroxyl ions is measured on a negative logarithmic scale from 1 (acidic) to 14 (alkaline): 7 being neutral. Various factors bring about changes in the pH of water. The high values of pH are associated with water points that receive wastes from human activities. As acidity increases, most metals become more water soluble and more toxic. Hence, pH was positively correlated with electrical conductance and total alkalinity. For determination of pH different methods were used; including, pH meter, Litmus paper and Colorimeter methods (USEPA, 2011).

2.2.5.10. Nitrogen as nitrate

Total oxidized nitrogen is the sum of nitrate and nitrite nitrogen. Nitrate generally occurs in trace quantities in surface water but may obtain high levels in some groundwater. Based on concentration range of nitrate, there are different methods for the determination of nitrate – nitrogen. These are: Ultraviolet spectrophotometer screening, Nitrate electrode screening, Cadmium Reduction, Chromo tropic Acid and Devarda's Alloy Reduction methods (Alemu *et al*., 2017). Nitrates are normally present in natural, drinking and wastewaters. It enters water supplies from the breakdown of natural vegetation, the use of chemical fertilizers in modern agriculture and from the oxidation of nitrogen compounds in sewage effluents and industrial wastes (USEPA, 2011).

2.2.5.11. Nitrogen as ammonia

Ammonia occurs as a breakdown product of nitrogenous material in natural waters. It is also found in domestic effluents and certain industrial wastewaters. Ammonia is harmful to fish and other forms of aquatic life and the ammonia level must be carefully controlled in water used for fish, farms and aquariums. Ammonia tests are routinely applied for pollution control on effluents and wastewaters, and for the monitoring of drinking water supplies The palintset ammonia test provides a simple method of measuring ammonia (ammoniacal nitrogen) (Abdullah-al-mamun *et al*., 2018).

2.2.5.12. Phosphate

Phosphate finds widespread application in the food processing industry and in industrial water treatment processes. Agricultural fertilizers normally contain phosphate minerals and phosphates also arise from the breakdown of plant materials and in animal wastes. It can enter water courses through a variety of routes-particularly domestic and industrial effluents and run-off from agricultural land. Phosphate is an important control test for natural and drinking waters. Using Palintest photometer colorimetric instrument; we can determine the amount of phosphate by dividing into two ways (APHA, 1999).

2.2.6. Environmental and health impact of coffee effluent

According to the USEPA, (2011), the discharging of the untreated waste from industries is threatening surface waters worldwide, and it is severe in developing countries. The coffee processing waste has been causing environmental problems at the local level due to the consumption a lot of water and generates a considerable amount of wastewater to the receiving environment. Organic and acetic acids formed from mucilage as the result of fermentations of the sugars, rich in dissolved solids and organic matter makes the wastewater very acidic a condition in which higher plants and animals can hardly survive (Tadesse & Alemayehu, 2016; Ulsido & Li, 2016).

Moreover, the total suspended solids in the effluents are high; when it precipitated out of the solutions, builds a crust on the surface, clogging up waterways and further contributing to the anaerobic conditions. Such wastewater directly discharged to the nearby water bodies and thus causing many severe health problems, these are spinning sensation, eye, ear and skin irritation, stomach pain, nausea and breathing problem among the residents of nearby areas (Asrat *et al.*, 2015). The wastewater emanated from wet coffee processing plants into the natural water bodies have a potential to pollute receiving water bodies, if the waste is discharged without any treatment (Ramya *et al.*, 2015).

2.2.7. Water quality standards

To safeguarded the sustainability of the natural system for the current and future users; it needs to manage and keep this system. In way of this, the industrial processes facilitate the development of the involved nations. But it generate huge amount of the effluent that may had different characteristics of the quality and may pose water/environmental pollution in the neighborhood pupils and environments a whole. So that the industrial effluents need to have its quality to be discharged into receiving environment such as surface water (lake, sea, rivers/steam, wetlands, and estuaries) and land resources. These standards and guideline were used from USEPA and Ethiopian EPA standards for surface water quality, Ethiopia Standard Agency for industrial effluent quality, WHO standards for surface water quality for aquatic life, laws, policies and legislations for safeguard of the environment (EEPA, 1997; FAO, 2000; USEPA, 2011: WHO, 2017).

3. MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location

This study was carried out in the Chichu River catchment, which is located in the Rift valley Lake basin of Ethiopia, specifically in Gidabo watershed. Geographically it lies at latitude of $6^{o}21'0''$ - $6^{o}24'30''$N and longitude of $38^{o}19'0''$ - $38^{o}24'0''$ E, and it covers 82.323 square kilometers of drainage area. According to the administrative map of Ethiopia, this catchment located in the Dilla zuria woreda of Gedeo zone, SNNPR. It suited at a distance of the 365 km south of Addis Ababa, capital of Ethiopia and 95 Km south of Hawassa, capital of Southern region. It drains to Gidabo watershed by confluencing with Walame River.

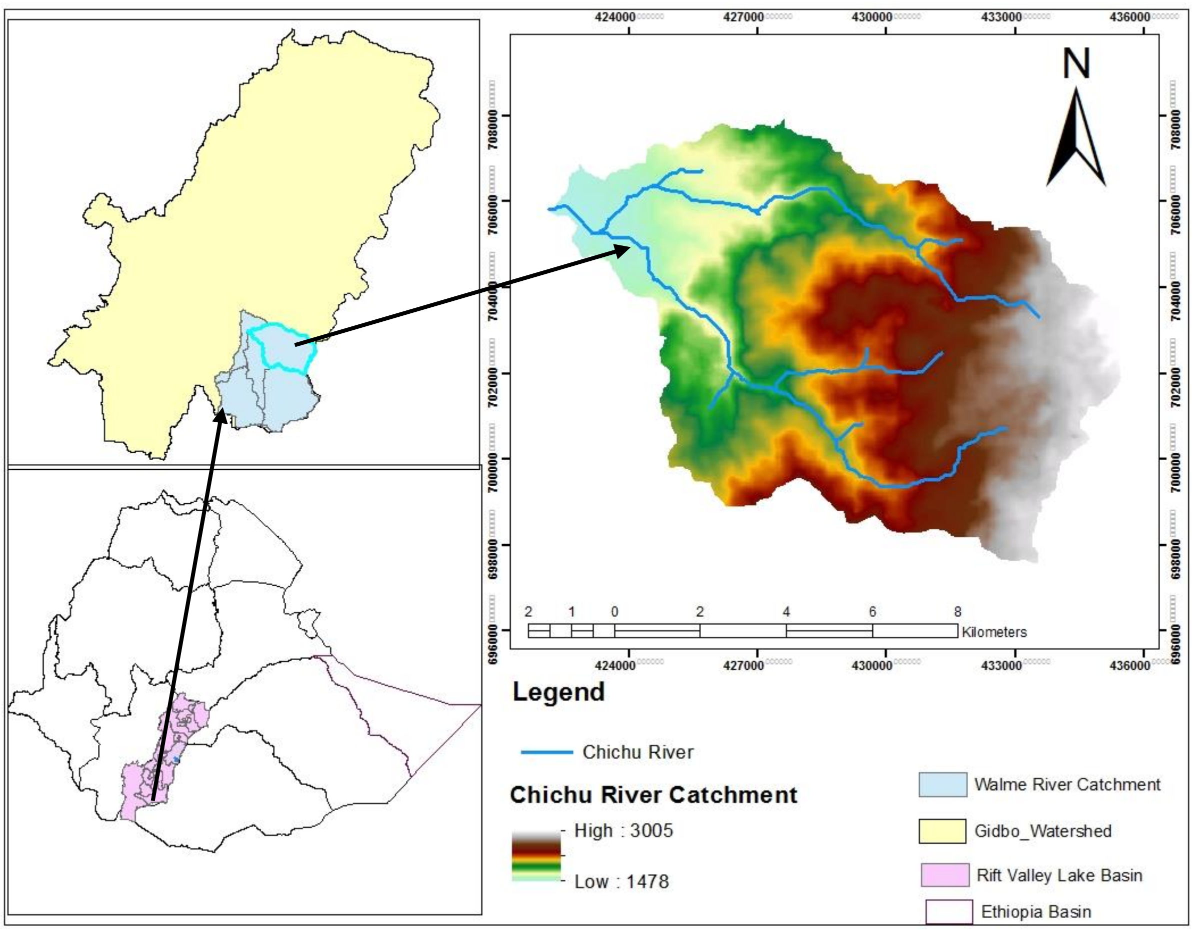

Figure 1: Study area (Chichu River catchment)

3.1.2 Climate

The climate condition of Ethiopia is controlled by seasonal migration of the inter-tropical convergence zone and influenced by complex topographic condition. Due to this the easterly and southeasterly moist air current arises over the highlands in the spring (March to May) and produce rainy season in the southeast Ethiopia. Therefore, Chichu River catchment receives maximum first and second rainfall during spring and autumn respectively. The catchment have long rainy season in the summer (locally called Kiremt) from June to September; this season represent greater than 60% of the mean annual rain (Asmerom, 2015).

The dry period locally called bega extends between October and February when the ITCZ lies to the south of Ethiopia. Generally, the study area receives bimodal type of rainfall with double peak rainfall pattern and the average annual rainfall is 1406 mm. The monthly rainfall distributions of the study area were given in Figure 2.

The catchment exhibit a humid type of climate that characterized by abundant moisture and relatively high temperature. The mean annual maximum and minimum temperature were 28.4 and 12.8°C, respectively (Figure 3).

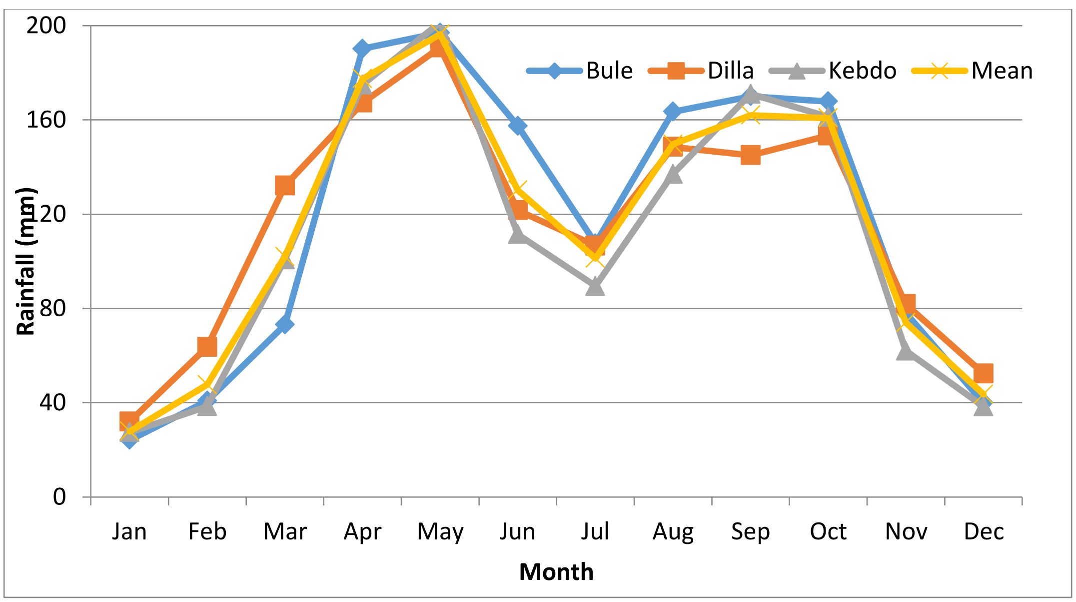

Figure 2: Monthly rainfall distribution of the study area

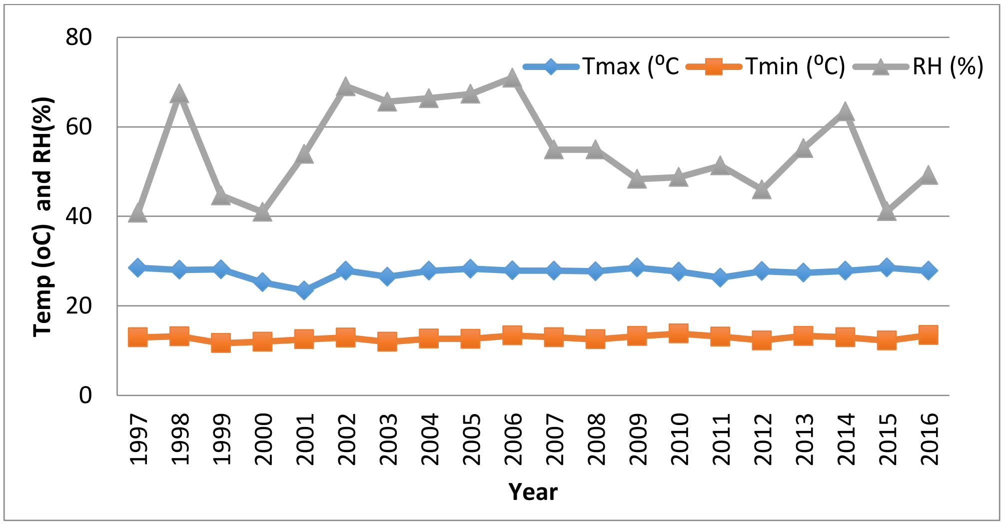

Figure 3: Annual maximum, minimum temperature and relative humidity of study area

3.1.3 Topography

The topography of the study area exhibits high altitude at the upstream of the catchment with elevation range from 1478 - 3005 m a.m.s.l (Figure 1). The upper altitude of the catchment expected to be free from pollution effect and water quality was at its natural condition, since most industries concentrated at the lower elevation area (Figure 8). Chichu River catchment slope reflects the rate of change in elevation with respect to distance along principal flow path. The slope of the catchment, in the lowland part lies between 0-15%, middle 15-30 % and the upper part was above 30 % (Figure 12).

3.1.4 Soil and land use/cover

The Chichu River catchment incorporates three major dominant soil groups of nitosols, leptosols and vertisols. The most part of the catchment is agricultural land dominated followed by forest, agro-forestry, built up, and bare land. The agricultural land as result of the favorable geographic and climatic condition; cash crop (coffee), legume, bean, inset, vegetables, maize and barley were dominant crops in study area. Built up area consists the Dilla town at the lower part of the catchment and the other parts it was rural small Kebles. And forest land of the catchment covered with perennial trees, this trees used as shed for coffee plants. Land use and soil map of the catchment described in Figure 10 and 11 respectively.

3.1.5 Hydrogeology and drainage system

As Chichu River catchment located in the Rift Valley Lake basin, its suited at the foot over 3005 m high latitude which coincides with the eastern fault of the rift valley. It expected that both shallow and deep groundwater are existed. According Gedeo Zone Water, Minerals and Electricity office (GZWMEO), the shallow groundwater expected to occur in the reddish brown soil and deep groundwater in the underlying volcanic rocks mainly within fractures and weathered zones layers of the sandy deposits between different lava flows (GZWMEO, 2019). The catchment surrounded with two permanent rivers of Legedar and Badessa (which confluenced with Chichu River, and form Walame river). Walame and Legeder join after a short distance from Dilla town and then drain into Gidabo watershed (Figure 1).

3.1.6 Farming and livelihood practice

Like any other parts of the Ethiopia the main economic activity of the study area is agriculture, from this activity cash crop production is widely practiced. The southern part of the Ethiopia is well known for coffee production due to preferable geographical condition. From this part Gedeo zone, is most prominent location for producing coffee. The farming system incorporates different crops; including vegetables, cereals, pluses, cash crop, inset and other agroforestry based cultivation was practiced. Next to the harvesting the coffee cherries, mainly processed via wet fermentation to get the parchment coffee.

Chichu River is one of the rivers in Gidabo watershed, in which multiple coffee processing industries were located following the bank of the river. According Gedeo zone office of agriculture GZANRO, (2019) from the total available wet coffee pulping mills of the zone it covers approximately 16 % or nineteen planted in the Chichu River catchment (Figure 8).

3.1.7 Demography

In Chichu River catchment both rural and urban population made their lives. It is a catchment in which populations were densely populated even in rural area. Based on the data of Dilla zuria worda the rural population was estimated to be 65,590 in the Kebele’s of the catchment (GZANRO, 2019). According to the census report of Ethiopia central statistical agency the total populations of the Dilla town were reported 101,957 (CSA, 2013) and a total population in the catchment estimated to be 200, 000.

3.2 Materials and tools

To response stated objectives of the study the following materials, data, and tools were used;

- To analyze background information for the study site selection and to cross-check land use/cover and soil of the study area; topographic map of the study area were used.
- By following the standard method for water and wastewater examination (APHA, 1999) the required instrument has been used for respective quality parameters in the field and laboratory analysis.
- Collected metrological, spatial and hydrological data were used for characterizing catchment hydrology for surface water estimation and water quality parameters data, were analyzed using SWAT 2012 and SPSS statistics version 20 respectively.
- For study area delineation and catchment characterization; description of sample points; for taking field image during field observation; to calibrate and validate model result ArcGIS 10.3, GPS, digital camera and SWAT-CUP were utilized respectively.
- Furthermore; to generate land use land cover map of the catchment Erdas Imagine 2014 and landsat image was utilized.

3.3 Methods

To carry out this study, collection of meteorological, hydrological, and spatial data and applying tools for analysis. The collected data were analyzed via ArcGIS 10.3 interface ArcSWAT 2012 model; which calibrated and validated by SWAT-CUP by doing so surface water resource potential of the catchment was estimated.

And also, collection and analysis of sample data for selected quality parameters. These include onsite and laboratory assessment of the sample data, which assisted with field observation of current study subject. The characterization of the sample data was done for raw river water (before receiving coffee effluent), coffee wastewater and downstream river water (water after receiving the coffee wastewater) by using twelve selected quality parameters that are more related to the coffee wastewater (Woldesenbet *et al.*, 2014; Kiran, 2018;). By doing so, the quality of the river water and effect of effluent evaluated with the quality standards (EEPA, 1997; FAO, 2000; USEPA, 2011 and WHO,2017).

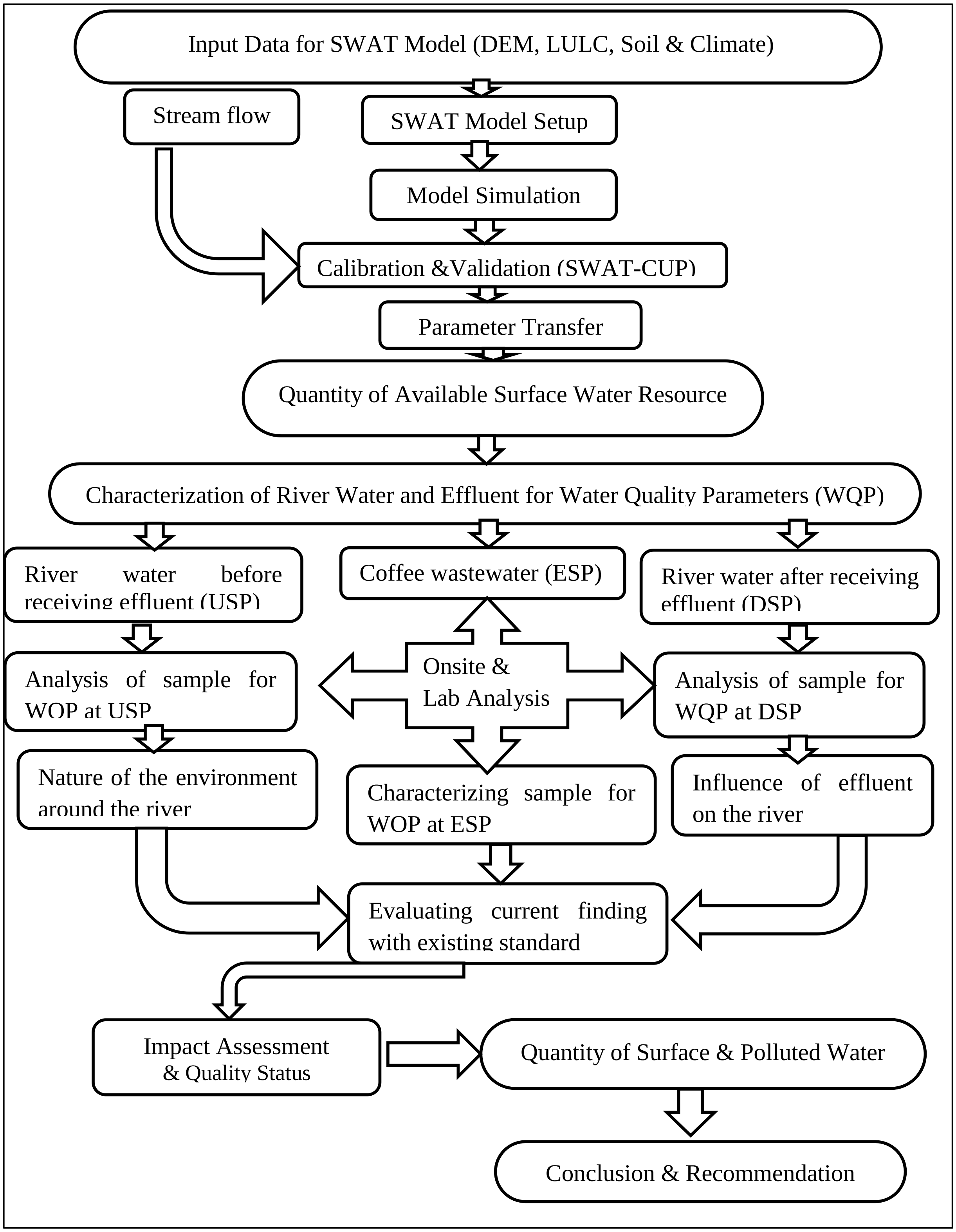

Figure 4: Conceptual framework of the study

3.3.1 Data collection and pre-processing for surface water resource estimation

3.3.1.1 Hydro-meteorological data

Hydro-metrological data are the most important data in hydrological simulation. It sourced from national meteorological agency of Ethiopia (NMAE). The meteorological data obtained from this agency includes precipitation, maximum and minimum air temperature, sunshine hour, wind speed, and relative humidity in daily basis.

The collected data covers a period of from 1997 to 2016 for the selected station based on the stations length of record period, and distribution of stations in and around the catchment; so depending on this three stations were selected for this study and only Dilla station is synoptic, which includes all parameters. Collected data may be inconsistent and irregular due to different reason, thus before using these data have to be checked and errors have to be removed using different methods.

- **Estimation missing rainfall data**

Rainfall data is one of the most important time series data; its data at certain rain gauge stations for a certain days may be missed due to damage or fault in a rain gauge during a period. In such cases, it may be needed to estimate the missing rainfall amount by approximating the value from nearby stations. Different methods (normal ratio method, inverse distance and arithmetic mean method) are available for filling missed records of the stations data.

The normal-ratio method is recommended to fill the missing data of a gauge station if the total annual rainfall at any of the nearby gauges differs from the annual rainfall at the point of interest by more than 10% (Raghunath, 2006). Thus, in this study missing records of the rainfall stations were estimated by using the normal ratio method (NRM). The NRM can be computed using equation 1.

$$Px = \frac{Nx}{n}\left(\frac{P1}{N1} + \frac{P2}{N2} + \cdots \frac{Pn}{Nn}\right) \quad (1)$$

Where p1, p2. . . pn :are the rainfall data of nearby stations; N1, N2, Nn :the normal annual rainfall of nearby stations; Px and Nx: the corresponding values for the missing station x in question and n: is the number of stations surrounding the station x.

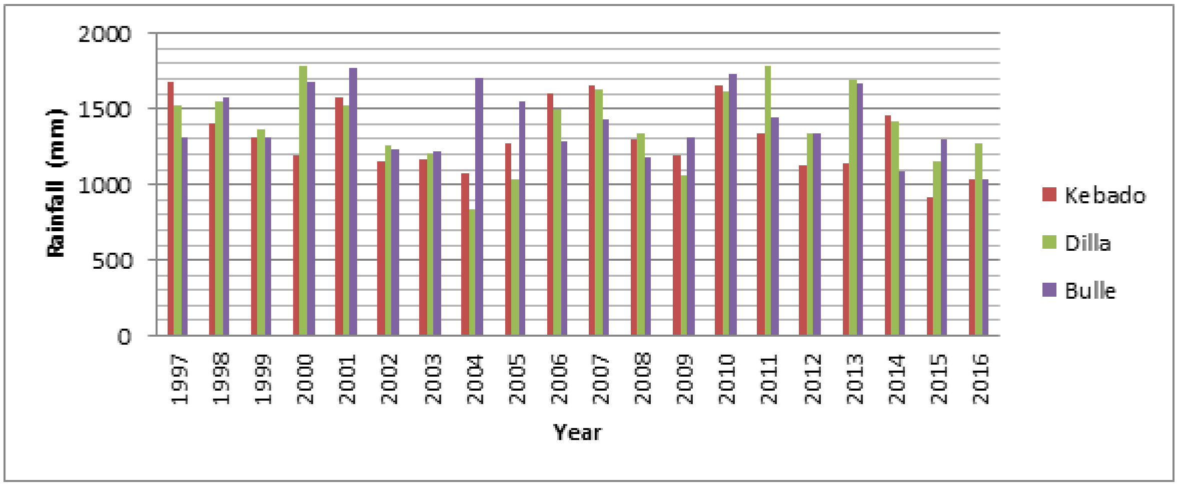

Figure 5: Annual rainfall distribution in study area

- **Checking consistency of the selected stations by double mass curve**

The inconsistencies of the rainfall data may raise as result of the conditions that relevant to the recording of a rain gauge station have undergone a significant change during the period of record. This inconsistency would be felt from the time the significant change took place. The checking for consistency of the record is done by double mass curve (DMC) techniques (Raghunath, 2006). DMC is the graphical method for identifying and adjusting inconsistency of a station recorded by comparing the accumulated totals of the gauge in the question with the corresponding totals for representative group of the nearby gauge. A decided change in the regime of the curve observed, it should be corrected by using equation 2.

$$Pm = \frac{Mc}{Ma} * Px \qquad (2)$$

Where: Pm is corrected precipitation at any time period, Px is original recorded precipitation at time period, Mc is corrected slope of the double mass curve and Ma is original slope of the double mass curve.

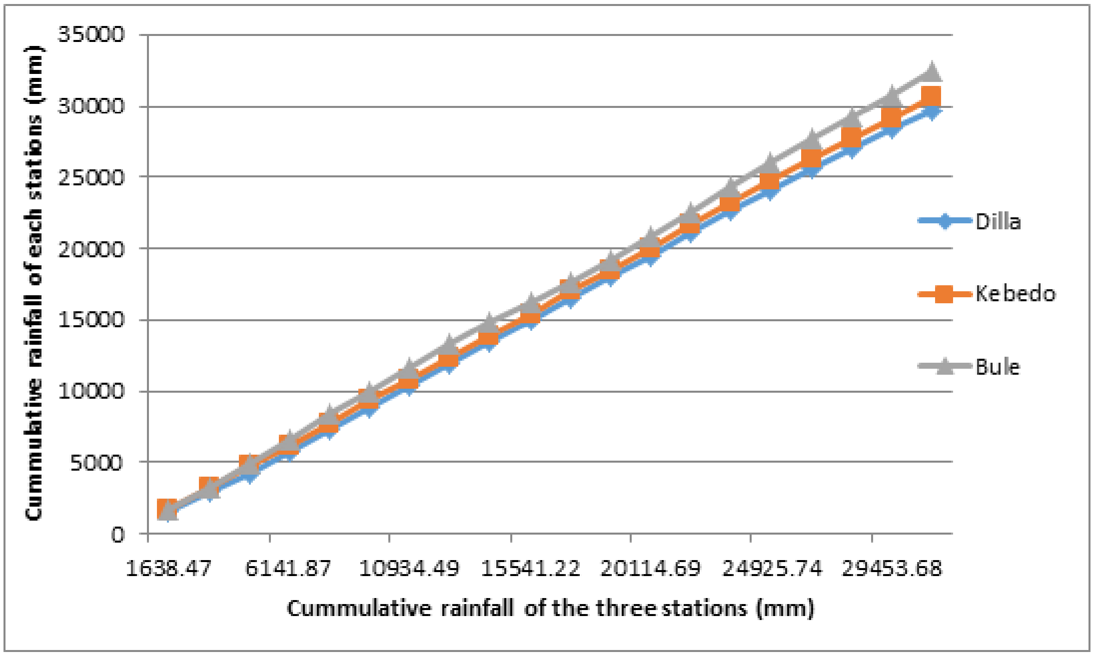

Figure 6: Double mass curve of the three stations

As depicted in figure 6, all points form almost straight line, which was plotted for checking of consistency of rainfall data, indicates that all stations were consistence. Therefore, the stations did not need further adjustment.

- **Stream flow data processing**

In this study stream flow data was the leading hydrologic data set, but Chichu River is one of the ungauged Rivers. To overcome this shortage of the data, a regionalization technique has been used. Based on this technique, the calibrated model parameters from gauged river used to transfer data. To do this the catchment that incorporate Chichu River as sub-basin to it and more proximate, similar with climate and physical condition was selected. Thus, gauged Walame River flow data measured near Dilla university (6^{o}23.5’30’’N and 38^{o}22’10’’ E) was used for calibration and validation of the model, which obtained from hydrology department of the MOWRE, from 1997 to 2010.

Collected daily stream flow data have missed values; the multiple regression method was used to fill missed records. And filled monthly flow data were used for model calibration and validation. As depicted in figure 7, stream flow on monthly average value correspond rainfall trends.

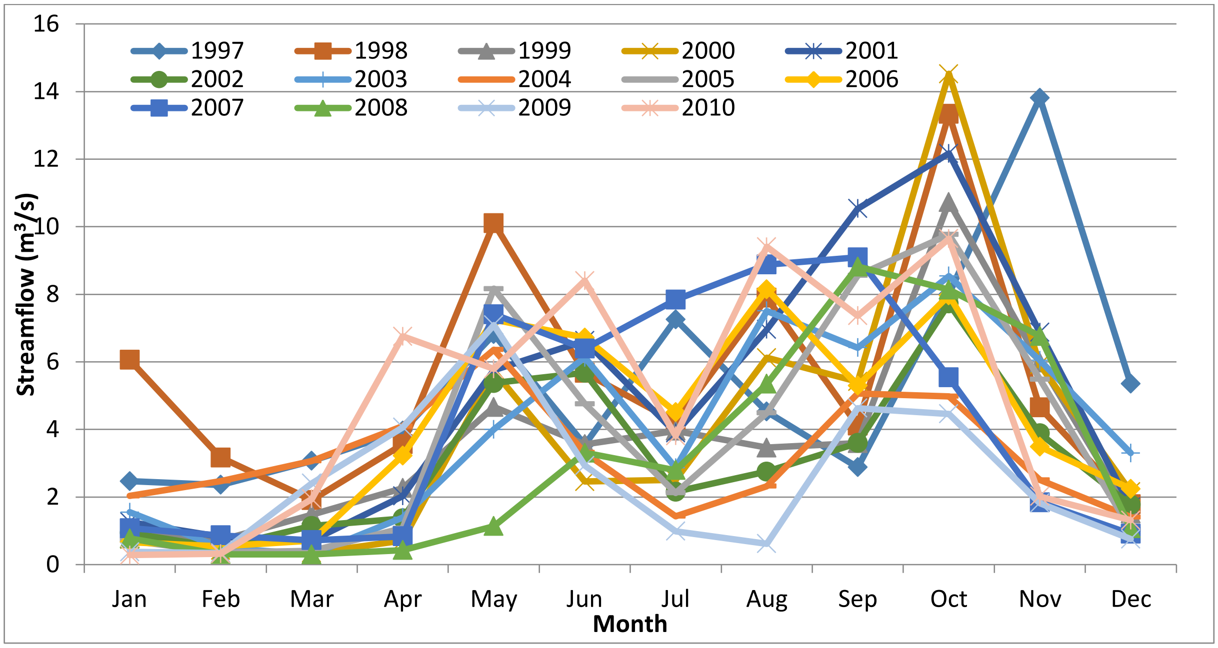

Figure 7: Average monthly observed stream flow data of the Walame River

3.3.1.2 Spatial data

The spatial data in this study includes; digital elevation model, land use/cover, and soil data which are mainly used to characterize the catchment hydrology and input data for SWAT model. The DEM for this study with a resolution of 30m x 30m, is obtained from MoWRE.

3.3.2. Water quality parameter investigation

3.3.2.1 Sampling technique for water quality parameters assessment

In this study purposive and composite sampling techniques were used. By using purposive sampling Chichu River selected as study site; since it receives effluents from nineteen plants that located following the banks of the river. As per APHA, (1999) and USEPA, (2011); composite sampling techniques were used for sample collection and analysis.

For analyzing quality parameters the main sources of samples were raw river water and coffee wastewater that generated from processing mills. Since all of the available wet coffee processing mills follow same processing method, they are expected to generate coffee wastewater of nearly similar composition and as result having the sample from whole mentioned plants was uneconomic.

So for investigation four sampling sites were selected; by taking the reference point from the upper part of the river in which the primary wet coffee processing mills were located and via checking unavailability of other plant prior to it. The sites were nominated as following;

- Sample site one (S1):- a site on the upper part of river in which the first wet coffee processing mill was located and prior to it there is no other plant. Its location is at highland part of catchment comparing to other, so this site used as reference point for other downstream sites for quality evaluation, and expected to be free from effect of the effluent discharge and pollution.
- Sample site two (S2):- is the site in which second processing mill located on the course of the river and used to evaluate the effect of effluent discharge from this plant and prior one, it referenced by S1 to compare the quality parameters;
- Sample site three (S3):- a site on the course of the river at 16th wet coffee processing plants and used evaluate the effect of effluent discharge from this plant and other 15 prior mills.
- Final downstream sample site (S4):- is site on the course of river after 18th wet coffee processing mills, this point used to examine overall effect of effluent discharge from multiple plants and how the residual constituents aggravate downstream water quality problem of the river. The overall quality of river water at this site (S4), referenced by the quality of the parameters that observed at S1.

For sample data collection, the selected sites were further differentiated into three respective points. This was done by taking plants location on the course of the river and effluent discharge point from the wet coffee processing mills. The distance between sampling points, assigned based on the procedure for water and wastewater examination (APHA, 1999), so the location of the sampling points at the course of the rivers were placed sufficiently upstream downstream 200m from effluent entry points. This is to ensure dispersion of the effluent over a wide cross section of the river. In all designated site, for example; at S1 the samples were collected by differentiating this point further into three sampling points;

- ✓ Upstream sampling point (USP): - a point prior to the effluent discharge on a distance of the 200m from the effluent point;

- ✓ Effluent sampling point (ESP): - a point in which the coffee wastewater discharged into the river; and
- ✓ Downstream sampling point (DSP):-a point which located at the distance of the 200m below the effluent discharge point.

By using GPS coordinates the sample site and overall wet coffee processing mills were described (Figure 8); the description was done following the course of river and wet coffee processing plant location on the river. And to take account for the tributaries of the river, the sites were selected by considering confluencing point of tributaries to the river (Table 1).

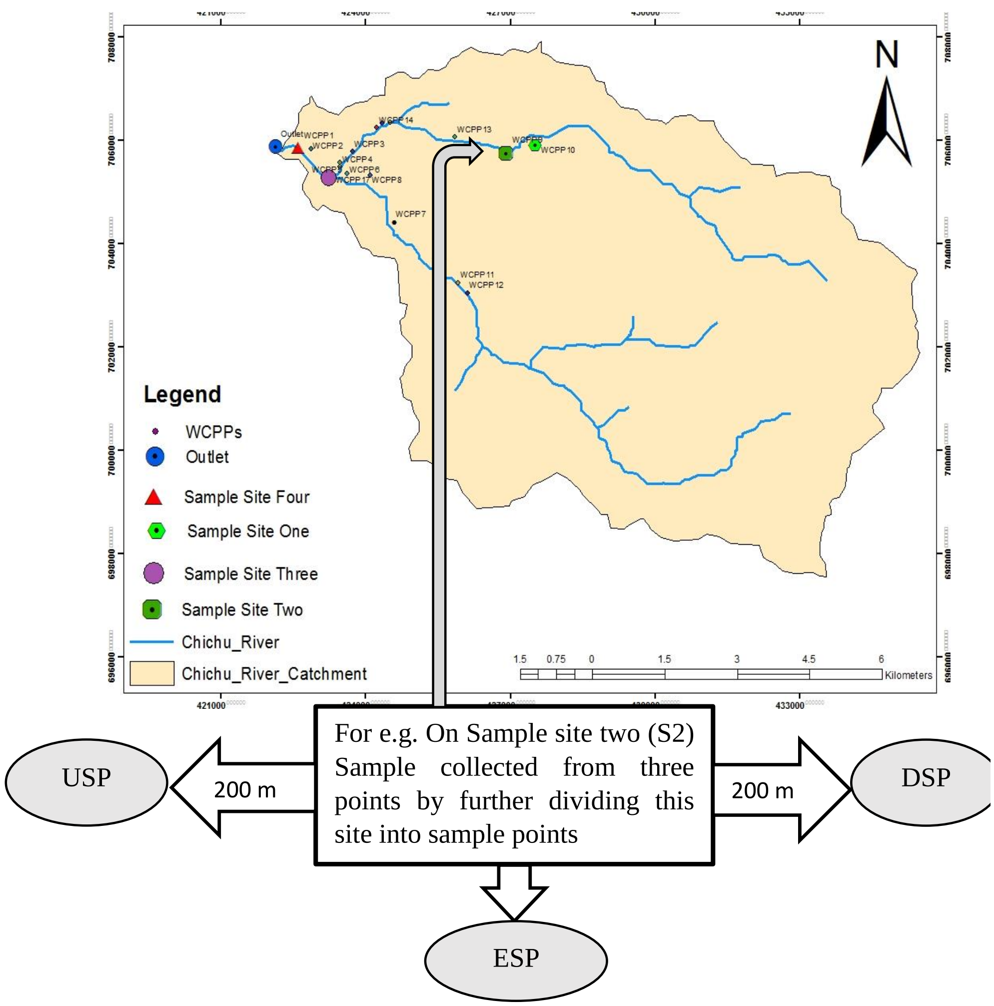

Figure 8: Schematic representation of the sample site and point in study area

Table 1: GPS coordinates for selected sampling sites

No	Sample site	Symbol	GPS coordinates		
			Easting	Northing	Altitude (m)
1	Most upper site on the river and primary mills was planted	S1	427521	705903	1672
2	2nd plant on the river & upper river course	S2	426900	705760	1648
3	16th plants on the courses of the river	S3	425853	706062	1535
4	Final downstream site 19th wet coffee processing plants on the river	S4	422598	705857	1488

3.3.2.2 Data collection for water quality parameters

For this study, the data were collected via onsite and laboratory analysis for selected quality parameters. Since the WCP mills in study area commencing their work on the October, discharging of the coffee wastewater begun in this month, so two months were used as period for sample collection on the peak season mainly from November 1 to December 30/2018.

To take representative sample from above stated points three replication were made and the care during collection, preservation and transportation was given to prevent other contamination. Analysis and preservation was made based on the guideline and procedures stated in USEPA (2011) and APHA (1999). All samples were collected using clean plastic bottles that were thoroughly washed with clean water by inserting the plastic bottle up to 40 cm depth to the opposite direction of the river flow.

By using above stated procedure, five quality parameters (Table 2) were analyzed onsite by using portable instruments. The instrument for onsite assessment and onsite measurement of the water and wastewater samples were given in appendix A.

For rest of quality parameters; after sample collected from the field, they are carefully preserved, labeled and transported for laboratory analysis (Table 2); TDS, TSS, NH_4^+-N_2, and NO^-_3-N_2 were analyzed at Hawassa University, water and wastewater quality laboratory. BOD and COD samples were examined in the SNNPR bureau of water and irrigation, water quality laboratory.

Table 2: Selected physiochemical quality parameters and techniques for analysis.

Quality parameters	Acronym	Unit	Methods of analysis & Instrument	Analysis
Water temperature	T	°C	Probes multi parameter, Thermometer (Model DT-613)	Onsite
Turbidity	TU	NTU	Turbidity meter, (Model TN-100)	,,
Electrical conductivity	EC	µS/cm	Probes multi parameter (EC meter, (CON-410))	,,
pH	pH	-	Probes multi parameter (Digital pH meter, (Model-S1-136))	,,
Dissolved oxygen	DO	mg/L	Probes multi parameter methods (DO meter, (Model HI-9143))	,,
Total dissolved solids	TDS	mg/L	Gravimetric Method, dried at 180°C	Lab
Total suspended solid	TSS	mg/L	Gravimetric Method, dried at 103-105°C	,,
Biological oxygen demand	BOD_5	mg/L	The Azide Modification of the Winkler Method, BOD Incubator (Model HACH-205).	,,
Chemical oxygen demand	COD	mg/L	Kit (Hachlange cuvette test, COD digester (HACH-BDR-200)	,,
Nitrate-nitrogen	$NO3\text{-}N_2$	mg/L	Phenoldisulfonic Acid Method	,,
Ammonia-nitrogen	$NH3\text{-}N_2$	mg/L	Direct Nesslerization Method	,,
Phosphate	PO_4^{3-}	mg/L	Kit (Hachlange cuvette test, Pagualab Photometre (Model 3460-010)	,,

Source: APHA, 1999

The standard analytical procedures for each selected parameter analysis were described and expressed as follows:-

- Temperature: The temperature of the sample was determined by using a handheld degree Celsius thermometer sealed with a liquid that expands or contracts as the temperature rises or falls. The temperature determination is made by taking water sample and immersing the thermometer into it for the sufficient period of time, until stabilized reading taken. Its values expressed in degree Celsius (^{0}C).
- Turbidity: Turbidity was measured using portable turbidity meter, to measure it the water sample the two parts of the tube were fit together squarely. The bottle containing water sample was manually shaken thoroughly for a couple of seconds to ensure uniform mixing before pouring into the tube. Then, by holding the tube by one hand water sample was poured slowly into the tube until the cross mark on the bottom of the tube just disappears. Finally the measurement is taken by reading turbidity scale marked on the side of tube that corresponds to the level of water in the tube. The turbidity units were reported in Nephelometric Turbidity Units (NTU), which measure the intensity of light being scattered when light is transmitted through a water sample.
- pH: The pH values of the given water samples was determined by using portable digital pH meter. The pH meter was calibrated into three point's pH 4.01, 7.00 and 10.01 using standard buffer calibration samples before analysis. Then probe of pH is inserted into the water sample and finally the pH value was directly taken from the value of reading on pH meter.
- Electrical conductivity (EC): The EC of the samples was analyzed by using portable conductivity meter (CON-410). A well calibrated EC meter probe tip beyond the upper steel band was immersed into the sample. Finally the result was recorded in micro Siemens per centimeter (µS/cm) after stable reading was observed on the conductivity meter.
- Total dissolved solids (TDS): The TDS of the samples was measured by gravimetric method. A well-mixed 100 ml water sample was filtered through a standard glass fiber filter, and the filtrate that passed through a filter was evaporated to dryness in a

weighed dish and dried to constant weight at 179 - 181°C. The increase in dish weight represents the total dissolved solids (APHA, 1999).

Calculations:

$$TDS\ \left(\frac{mg}{L}\right) = \frac{(A - B)x\ 1000}{(volume\ of\ sample,\ \ mL)} \quad (3)$$

Where, A = weight of dried residue + dish, mg, and

B = weight of dish, mg

- Total suspended solids (TSS): TSS of the sample is determined by Gravimetric method, in which TSS was determined gravimetrically i.e., well-mixed 100 ml water samples was filtered through a weighed standard glass-fiber filter and the residue retained on the filter was dried to a constant weight at 103 to 105°C. The increase in weight of the filter represents the TSS (APHA, 1999). For measuring of the TSS Electronic balance instrument (Model Hzy-A200), Universal Oven (Model-0388663), and filter paper (0.045 µm) were used.

Calculation:

$$TSS\ \left(\frac{mg}{L}\right) = \frac{(A - B)x\ 1000}{(volume\ of\ sample,\ \ mL)} \quad (4)$$

Where, A = weight of filter + dried residue, mg, and

B = weight of the filter

- Biological Oxygen Demand (BOD_5) was determined by the Azide modification of the winkler's titrimetric method by determining DO contents of the samples before and after 5 days incubation at 20 ^{0}C and by using BOD Incubator (Model HACH-205).
- COD were analyzed by using COD digester (HACH-BDR-200) instrument.
- For determining selected nutrient parameters triplicate method was performed, so that Nitrogen-Nitrate (NO_3-N), ammonia (NH_4^+-N) and phosphate were determined by Phenoldisulfonic acid, and Pagualab Photometre (Model 3460-010) instruments.

3.3.3 Data analysis

3.3.3.1 Data processing for water resource estimation

For assessing surface water resource of the catchment, the SWAT model was used. To calibrate and validate simulated model result SWAT-CUP by using observed flow data were used. Since the river is ungauaged, Walame River flow data used for calibration and validation. Finally calibrated parameters from gauged Walame River transferring to Chichu River; thus the surface water resource of the catchment estimated.

3.3.3.1.1. SWAT model setup

SWAT model is an ArcGIS extension with its own user interface incorporates; SWAT project setup, watershed delineator, HRU analysis, Write Input Tables, Edit SWAT input and SWAT simulation (Inchell *et al*., 2013). The directory is opened and new SWAT project was set up and saved, and then watershed delineation was performed. In order to delineate the watershed, automatic watershed delineation was selected. Then, the DEM was added and stream network was defined. Finally, the whole watershed outlet and sub-basin outlet were manually added and the catchment divided into five sub-basins. The sub-basins possess a geographical position in watershed and they are spatially related to one another.

- **Digital elevation model data**

The digital elevation model (DEM) is digital representation of a topographic surface and it is available in the form of raster or regular grid of spot heights. It mainly used: - to define topography of the catchment via descriptions of the elevation; to delineate watershed boundary and sub-watershed; and to analyze stream networks and drainage pattern at any point in the given area at specific resolution. And also topographic parameters such as slope gradient, slope length of the terrain, and the stream network characteristics such as channel slope, length, and width were derived from the DEM. This was performed by the pre-processing module of the SWAT but requires a so called minimum threshold area.

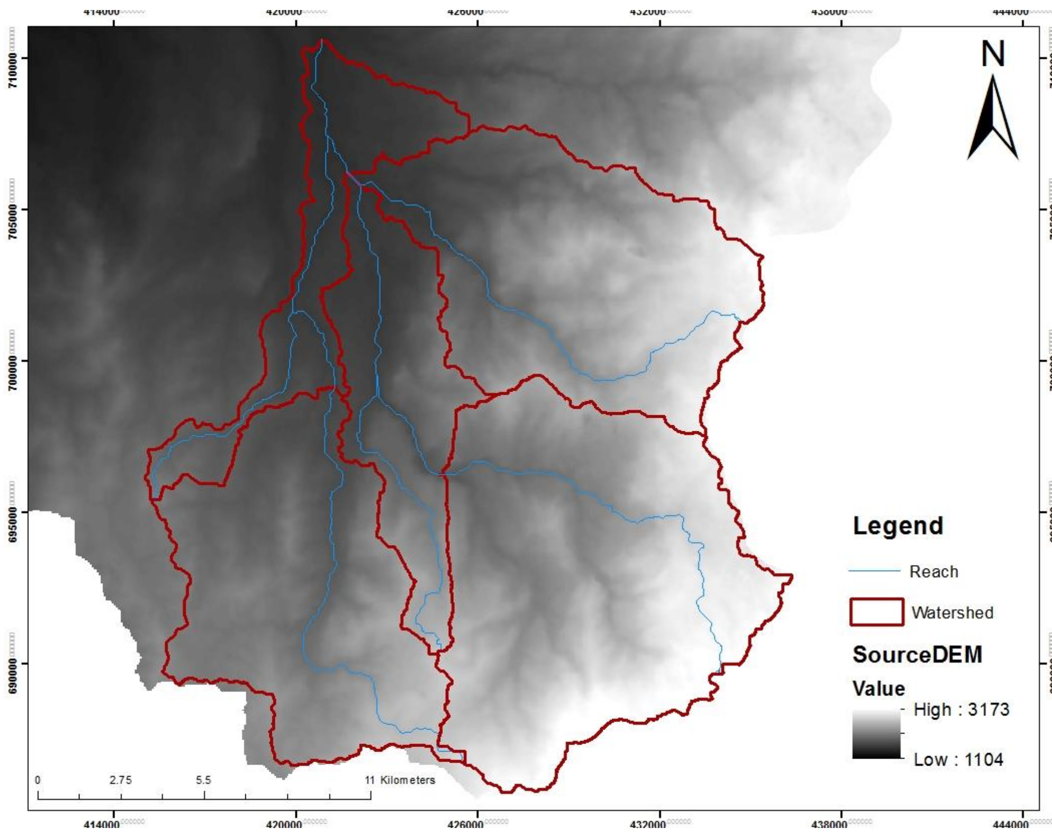

Figure 9: Source DEM data for SWAT model setup for Walame River catchment

- **Land use /land cover data**

The land use land cover (LULC) map of the area was prepared from the Landsat 8 satellite image with a spatial resolution of 30 m. The satellite image of the area was downloaded from USGS database website (http://earthexplorer.usgs.gov). The image was used for the preparation of LULC map based on supervised classification technique in Erdas Imagine 2014 software using a ground truth data points collected from field observation, topographic map and Google earth.

Land use classification of the catchment indicates that open forest, agricultural land, dense forest, grass land, urban and bare land covered a 34.81%, 28.72%, 21.05, 10.67%, 2.08% and 1.63% respectively. The agricultural land cover consists of perennial crops (coffee, inset, and fruit), and other annual crops (maize, wheat, legume, bean, vegetables, and barely). The open forest dominantly covered by perennial crops consists of shade trees with coffee, banana, inset, and sugarcane. Built up area mainly consists of urban area of Dilla town, and other small towns such as Bule, Wongo, and Chichu.

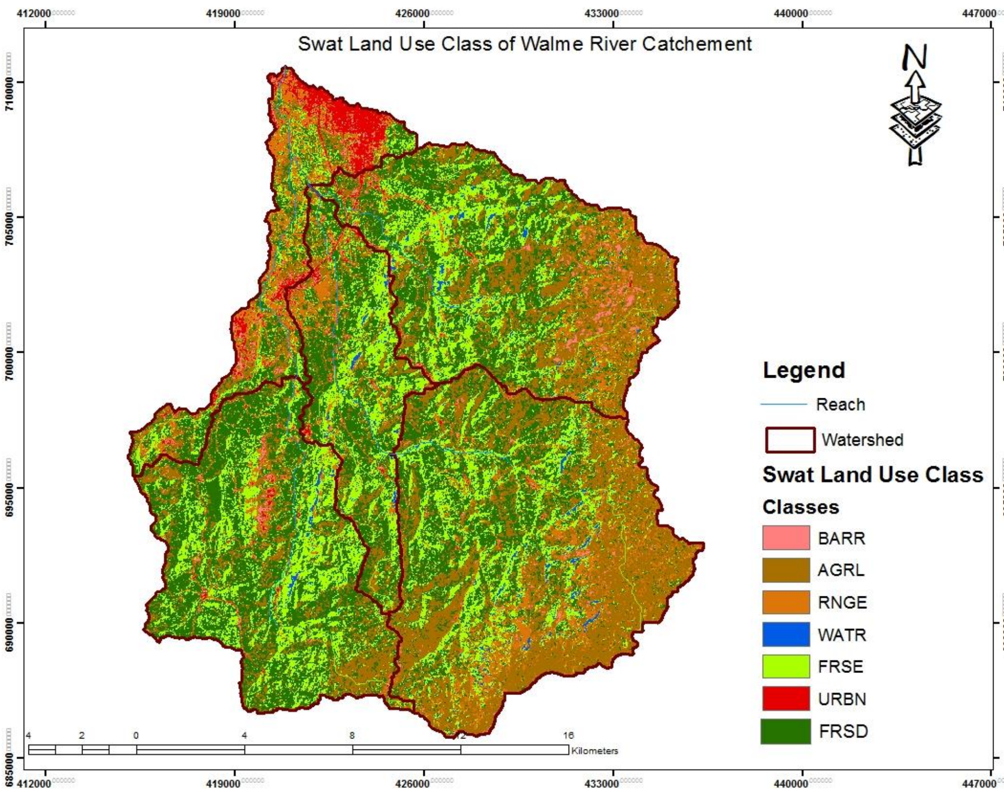

Figure 10: SWAT land use class of Walame River catchment

LULC is one of the most important spatial input data for SWAT model that affects runoff, evapotranspiration, surface erosion and other hydrological process in a given catchment. Spatial distribution and specific land use parameters were required for modeling. SWAT has predefined land uses type identified by four letter codes and it uses these codes to link land use maps to SWAT land use database in the GIS interface. So preparing the lookup table for land use types were made compatible with the input needs by the model.

- **Soil data**

The soil map obtained from MoWR for Rift Valley Lake basin (RVLB) used to identify the soil distribution within the catchment to be used for SWAT. By using shape of study area the dominant soil types were clipped for the catchment. Based on the clipped data the dominant soil types are; Hpluvisols (53.34 %), letleptosols (23.45%) and leptosols (16.76%)

The textural and physicochemical properties of the soils required by the SWAT model include soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type. The value of these soil parameters (properties) for each soil type and soil layer was collected from harmonizes world soil database viewer program (FAO, 2000).

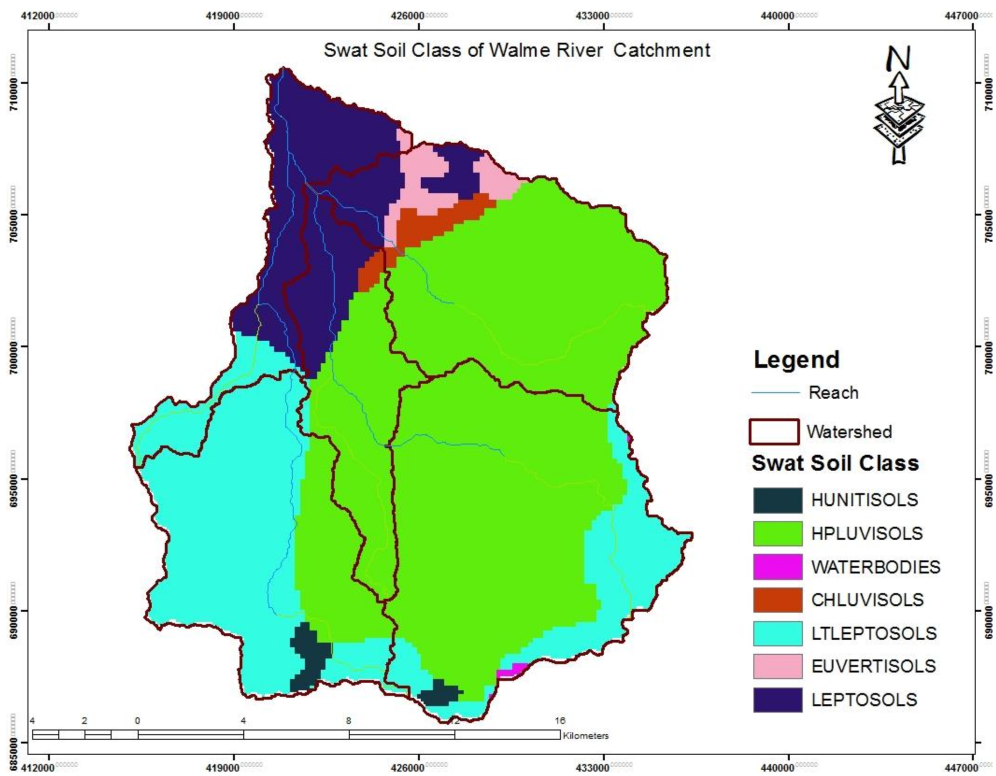

Figure 11: SWAT soil class of the Walame River catchment

- **SWAT slope class**

In addition to the land use and soil data, the SWAT model uses slope class for generating hydrologic response units for the catchment. This slope class generated from DEM data and further differentiated into multiple slope class. Based on the available threshold value of the classification, the overall slope of the catchment classified into four classes and the most dominant classes included in the value greater than 15 % of the slope. These indicate that the Walame and Chichu river catchment exhibit rugged and steep land slope.

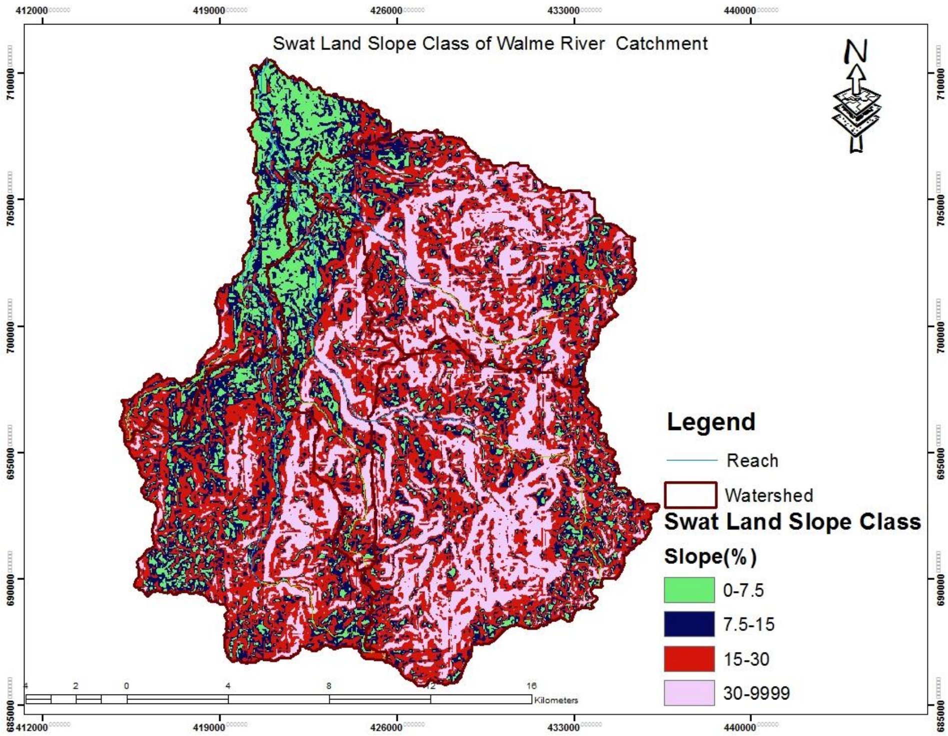

Figure 12: SWAT land slope classes of Walame River catchment

- **Hydrologic response unit (HRU)**

Once the sub-basin delineation is completed, the user has the option of modeling a soil, land use and slope for partitioning the sub-basins into multiple hydrological response units (HRUs). HRUs are portion of a sub-basin that possesses unique land use, slope and soil attributes. A sub-basin contains at least one HRU, a tributary channel and a main channel or reach. HRU are used in SWAT model to simplify a run by lumping all similar soil, slope and land use areas into a single response unit and it will increase the accuracy (Neitsh et al., 2005).

After overlaying land use/soil/slop dates, HRU definition was performed by using the land use, soil and slope threshold value (15%, 15% and 10%) respectively used for classification. By using these data, SWAT classified the watershed into seventy one HRUs.

- **Weather data definition and writing of input table**

Subsequently HRU definition was carried out, writing of input tables was continued by defining weather data and weather generator data. To define the weather generator data, the user weather station was created and the weather station parameters were fitted in the new station. In order to prepare the station parameters, different processing software were used including;

- ✓ The program dew02.exe was used to calculate the average daily dewpoint temperature per month using daily temperature and humidity data.
- ✓ The program pcpSTAT.exe was used to calculate statistical parameters of daily precipitation data used by weather generator of SWAT model (Neitsh *et al*., 2005).

And the result from these processing software's (appendix E) were used in Microsoft excel sheet in the format compatible for the model. Then, SWAT model used weather generator (WGN) to fill missing information and simulate weather data for other stations that miss other parameters. To finalize the weather writing part, all sections written in the weather-writing part and all the watershed data was written and the model was made ready to be run. Once the model was run with default parameter setting, the sensitivity analysis, calibration and validation was performed.

- ➢ **Model parameters and sensitivity analysis**

The simulated and observed values for the flow may differ, in order to minimize this variation it is essential to determine the parameters which are affecting model simulation. To check these model parameters are to be known and its effect should be evaluated via sensitivity analysis. For this study, seventeen parameters were used for analysis (Neitsh *et al*., 2005 & Inchell *et al*., 2013) (Table 3).

Table 3: The common parameters in SWAT model for sensitivity analysis

No	Parameter	Definition	Lower Bound	Upper Bound	Range
1	Alpha_Bf	BAseflow alpha factor (days)	0	1	0 - 1
2	Gw_Delay	Groundwater delay (days)	-10	10	0 - 500
3	Gw_Revap	Groundwater "revap" coefficient	-0.036	0.036	0 .02 - 0.2
4	Gwqmn	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)	-1000	1000	0 - 5000
5	Revapmn	Threshold depth of water in the shallow aquifer for "revap" to occur (mm)	-100	100	0 - 500
6	Ch_K2	Effective hydraulic conductivity (mm/hr)	0	150	0 - 500
7	Ch_N2	Manning's nvalue for main channel	0	1	0 - 0.3
8	Epco	plant water uptake compensation factor	0	1	0 - 1
9	Esco	soil evaporation compensation factor	0	1	0 - 1
10	Sol_BD	Soil bulk density	-25	25	0 – 0.3
11	Sol_Awc	soil available water capacity	-25	25	0 - 1
12	Sol_K	hydraulic conductivity of saturated soil	-25	25	0 - 2000
13	Sol_Z	Depth from soil surface to bottom layer (mm)	-25	25	0 - 3500
14	Cn2	curve number	-25	25	35 -98
15	Surlag	runoff delay coefficient	0	10	0 - 10
16	Slope	Average slope steepness (m/m)	-25	25	0 - 999
17	Slsubbsn	Average slope length (m)	-25	25	10 - 150

Sensitivity analysis indicates how the changes in parameter values affect the overall change in the output of the model. This can be done by using default sensitivity analysis, where only one parameter is changed or more complex arrangements that explore the relationships between multiple parameters. Thus, a sensitivity analysis performed for the entire period (1999- 2016). Then, eight the most sensitive parameters were obtained and used for calibration and validation of the model.

The sensitivity analysis was done by using SWAT-CUP, in which observed flow data, simulated flow data and the sensitive parameter in relation to flow with the absolute lower and upper bound were used as inputs. According to the Lenhart *et al*, (2002) after sensitivity analysis, the sensitive parameters were categorized into four classes based on their mean relative sensitivity (Table 4). According to this table, the model parameters were fall from small/negligible to very high sensitive to the model. Thus, the parameters that found in the index of $|I| \geq 1.00$ taken as most sensitive parameters for the model.

Table 4: Sensitivity classes of the model parameters

Class	Index(I)	Sensitivity
I	$0.00 \leq \|I\| < 0.05$	Small to negligible
II	$0.05 \leq \|I\| < 0.20$	Medium
III	$0.20 \leq \|I\| < 1.00$	High
IV	$\|I\| \geq 1.00$	Very high

Source: Lenhart *et al*., (2002)

- **Model calibration and validation**

In this study the calibration of SWAT model was done manually on monthly time step by using the measured flow data, sensitive parameters and by changing the more sensitive parameter at a time while keeping the rest parameters constant. It performed until the best-fit curve of simulated versus measured flow was obtained. The sensitive parameters were adjusted based on the allowable range until the best fitting value was found (Neitsh *et al*., 2005). In this process, model sensitive parameters varied until recorded flow patterns were accurately simulated. In this study, the calibration of the model was carried out for 8 years (January 1, 1999- December 31, 2006); since first two years considered as warm up period. Calibration of model was done at outlet of Walame River; since measured flow data were taken for this point.

After calibration of the model and the optimized parameters were found; validation of model followed using measured flow data. This is the process of representing a given model capability in making accurate predictions for specific site. By doing so, the validation of SWAT model was performed for the next four years from the period January 1, 2007 to December 31, 2010.

- **Model performance evaluation**

For evaluating the goodness of fit between the simulated and observed values during calibration and validation process different numerical model performance measures were used. They measure how well trends in the measured data are reproduced by the simulated results over a specified time period and these measures were computed for monthly time step (Abbaspour, 2015). In this study to evaluate model performance the coefficient of determination (R^2), and Nash-Suttcliffe simulation efficiency (NS) has been utilized. Their computed value for R^2>0.6, and NS>0.5 are good fit for the model. The computation of their values and descriptions are as follows;

a. **Coefficient of determination (R^2):** is dimensionless evaluation of model performance, ranging between 0 and 1, and interpreted as the correlation of variability in the observed and simulated values. Its values close to 1 indicate more efficient simulation and R^2 > 0.6 indicate good fit for model.

$$R^2 = \frac{((\sum_{i=1}^{n}(\text{Qsi} - \overline{Qs})(\text{Qoi} - \overline{Qo}))^2}{(\sum_{i=1}^{n}(\text{Qsi} - \overline{Qs}))^2(\sum_{i=1}^{n}(\text{Qoi} - \overline{Qo}))^2} \quad (5)$$

Where; Qsi and Qoi are the simulated and measured value of the quantity in each model time step respectively, Qs¯and Qo¯ are the average simulated and measured value of the quantity in each model time step respectively.

b. **Nash-Suttcliffe simulation efficiency (NS)**: is the systematic differences in magnitude of scale that are not detected with the correlation coefficient will already be relevant, however, the NS is still a statistic sensitive to outliers (Nash *et al.*, 2005)
Its value NS > 0.5 shows that the simulated model result was acceptable.

$$\text{NS} = 1 - \frac{\sum_{i=1}^{n}(Qoi - Qsi)^2}{(\sum_{i=1}^{n}(\text{Qoi} - \overline{Qo}))^2} \quad (6)$$

Where: - Qsi and Qoi are the simulated and measured value of the quantity in each model time step respectively and Qo¯ is the average measured value of the quantity in the each model time step.

3.3.3.1.2. Runoff estimation in ungauged Chichu River catchment

Chichu River is one of the ungagged rivers and modeling in it poses difficulty, because hydrological models need measured flow data to calibrate the simulation process. To overcome this difficulty, the regionalization technique was adopted for this study to predict runoff in ungauged catchment.

Regionalization is the techniques of transferring calibrated model parameters of gauged river to ungaged one; this may done based on similarity of catchment characteristics such as topography, slope, land cover, soil type, and climate. It is the process of transferring information from comparable catchments to the catchment of interest (Perera, 2009; Patil, 2011; Kerimi, 2017).

After calibration of the SWAT model for the gauged Walame River catchment, the final calibrated parameters were used to predict runoff and water balance component of the ungauged Chichu River sub catchment, which have similar hydro meteorological and physical conditions based on hydrologic response units (HRU) similarity (Neitsh *et al*., 2012). The Walame catchment was divided into 5 sub-basins and by using outlet of the Chuchu River, the catchment was delineated as second sub catchments. And the whole Walame River catchment further differentiated into seventy one HRUs.

- **Estimation of surface water resource via SWAT model**

The simulation of the hydrologic cycle of the land phase by SWAT is based on the water balance equation 7:

$$SWt = SWo + \sum_{i=0}^{t}(P\,day - Qsurf - Ea - wseep - Qgw) \tag{7}$$

Where; SWt, SWo, P_{day} Qsurf, Ea, w_{seep} and Q_{gw} are respectively final soil water content (mm), initial soil water content on day i (mm), t = time (days), amount of precipitation on day i (mm), amount of surface runoff on day i(mm), amount of the evapotranspiration on day i (mm), the amount of the water entering the vedose zone from the soil profile on day i(mm), and amount of the return flow on day i(mm).

For estimation of surface runoff, SWAT model uses two methods based on the concept of infiltration and excess runoff. It assumes that runoff occurs whenever the rainfall intensity is greater than the rate of infiltration. These methods are soil conservation curve number method and Green and Ampt infiltration method. For this particular research, the soil conservation services (SCS) curve number method has been used, due to unavailability of hydrological and meteorological data at sub-daily scale. CN-method is common method to determine the surface runoff generation by SWAT model. Which was initially designed for determining runoff generation for engineering design purposes, but has been adapted for use as implement in many temporal watershed models (Neitsch *et al*., 2005).

According to the Neitsch *et al*., (2005), in this method the land use and soil properties are lumped in to a single parameter. And also uses Natural Resource Conservation Service (NRCS) soil classification based on infiltration properties of the soil in to four groups (A, B, C, D) having high, moderate, low and very low infiltration rate respectively. In the classification, a soil group has similar runoff potential under similar storm and cover condition.

To determine CN, the model then defines antecedent moisture condition based on CN–antecedent moisture condition and soil moisture content that calculated by the model. The retention parameter (S) then determined using the daily CN value.

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \qquad (8)$$

The direct runoff is determined by integrating the above empirical model with SCS runoff equation.

$$Qsurf = \frac{(Pday - Ia)^2}{(Pday + 0.8\,S)} \qquad (9)$$

Where Qsurf is the surface runoff or rainfall excess (mm), Pday is precipitation depth for the day (mm), S is the retention parameter (mm) and Ia is the initial abstraction which usually approximated as 0.2S.

3.3.3.2 Data analysis for water quality parameters

Collected data from onsite and laboratory investigation were analyzed by applying statistical tools. Microsoft excel for inputting all values that obtained from onsite and laboratory analysis; descriptive statistics, including identifying mean, standard deviation, and variance of the sample were carried out. And narrations for field observation on current environmental condition were made.

Statistical tools, SPSS Statistic 20.0 version has been utilized for analyzing one way analysis of the variance (one way ANOVA). One way ANOVA was computed to see the significant differences between each sample site and points for water quality parameters. And mean separation of different sources of variations among each sample site and points was done via Turky's test at $\alpha=0.05$ level of minimum significance differences. By doing so, the quality of the physiochemical, and nutrient parameters at different sampling points (upstream, effluent discharge and downstream) were evaluated for its variation within site and between points.

After analyzing the all parameters in this way, the comparison and evaluation of the value with available standards and guidelines of different legislative bodies including; (EEPA,1997; FAO, 2000; USEPA, 2011; and WHO, 2017) for the suitability of the river water quality at downstream points were validated for fitness of the various beneficial purposes.

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4. RESULT AND DISCUSSION

4.1 Estimation of surface water resource potential

4.1.1 Sensitivity analysis

Sensitivity analysis was done by using seventeen model parameters (Table 3) for the modeling period (1999-2016). Thus, the result of the sensitivity analysis showed that eight parameters are sensitive to the SWAT model (Table 5).

Table 5: SWAT model sensitive parameters based on t and p value

Parameter	Definition	t- Stat	p-value	Rank
GW_DELAY.gw	Groundwater delay in the day	21.845	1.0E-6	1
SOL_AWC.sol	Available water capacity of the soil layer	3.512	5.0E-04	2
CN2.mgt	SCS runoff curve number	3.259	1.2E-03	3
ALPHA_BF.gw	Baseflow alpha factor, days	-1.990	4.7E-02	4
SOL_BD.sol	Soil bulk density	-1.554	1.2E-01	5
SOL_K.sol	Saturated hydraulic conductivity	0.532	5.9E-01	6
GWQMN.gw	Threshold depth of water in shallow aquifer required for return flow to occur (mm)	-0.487	6.3E-01	7
ESCO.hru	Soil evaporation compensation factor	-0.394	6.9E-01	8

Groundwater delay in the day (GW_DELY) is the first ranked parameter and which is the required time for water leaving the bottom of the root zone to reach the shallow aquifer, which contribute to lateral ground water flow. The soil available water (SOL_AWC), curve number (CN2_M), ALPHA_BF.bn, soil bulk density (SOL_BD), hydraulic conductivity (SOL_K), GWQMN.gw and ESCO.hru (soil evaporation compensation factor) were followed respectively. ESCO.hru, has direct influence on the evapotranspiration losses form the watershed and mainly controlled by soil characteristics.

As revealed in Table 5 and Figure 13, the sensitivity of the model parameters was evaluated based on the t-Stat and P-value. Which shows parameter’s sensitiveness to the model; the absolute value of the t-Stat is larger for more sensitive parameters and P-values is approaching to zero for more sensitive parameters (Khairi *et al*., 2016).

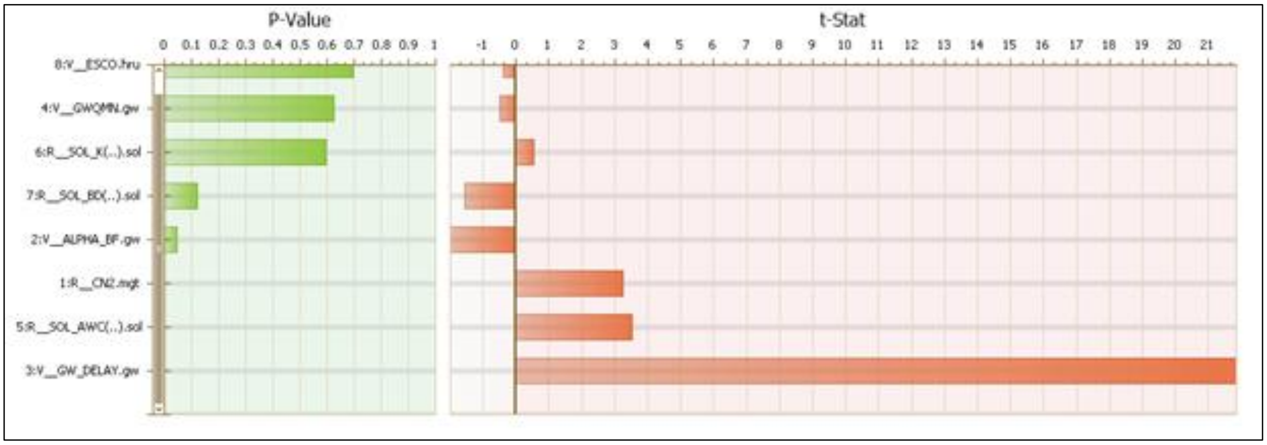

Figure 13: P-value and t-Stat of sensitive model parameters

Generally, the result of sensitivity analysis for the Walame River catchment shows the groundwater and soil based parameters had influence on the watershed runoff generation. This indicates that catchment's hydrology was controlled by subsurface flow, since agriculture and forest dominated watershed has less surface runoff generation. As reported by Smarzy *et al*., (2016), agricultural and forest based small watershed has less surface runoff potential, but the catchments rainfall is infiltrated directly to the soil, depending on the catchment properties.

4.1.2 SWAT model calibration and validation

The fitted parameter's value for Walame River catchment is described in the Table 6. This table shows, the calibrated model parameters exhibit significant variation, it indicates model calibration is vital to evaluate simulated and observed value. Through fitted parameters, the simulated value on monthly basis was obtained and the comparison of this and observed value was done on monthly basis for calibration. The resulted hydrograph of simulated and observed values are described in Figure 14. As depicted in this graph, the model starts simulation with overestimating the flow for the catchment and underestimates the peak flow especially for rainy months.

Table 6: Fitted parameter value after model calibration

Parameters	Fitted Value	Min_value	Max_value
GW_DELAY.gw	134.474991	30.000000	450.000000
SOL_AWC (...).sol	0.172750	-0.200000	0.400000
CN2.mgt	-0.065500	-0.200000	0.200000
ALPHA_BF.gw	0.001250	0.000000	1.000000
SOL_BD (...).sol	0.026625	-0.500000	0.600000
SOL_K (...).sol	-0.250000	-0.800000	0.800000
GWQMN.gw	0.747500	0.000000	2.000000
ESCO.hru	0.899250	0.800000	1.000000

The overall calibration of the model shows a good performance in the hydrologic simulation. Thus, model performed well in simulating the flow that compared with observed flow data. The performance indicator for model evaluation shows a good fit, 0.69, and 0.53 respectively for coefficient of determination (R^2) and Nash-Suttcliffe simulation efficiency (NS). This represents there is a good agreement between simulated and observed values. And then water resource of the catchment estimated after model validations, which done by using fitted parameters via calibration step.

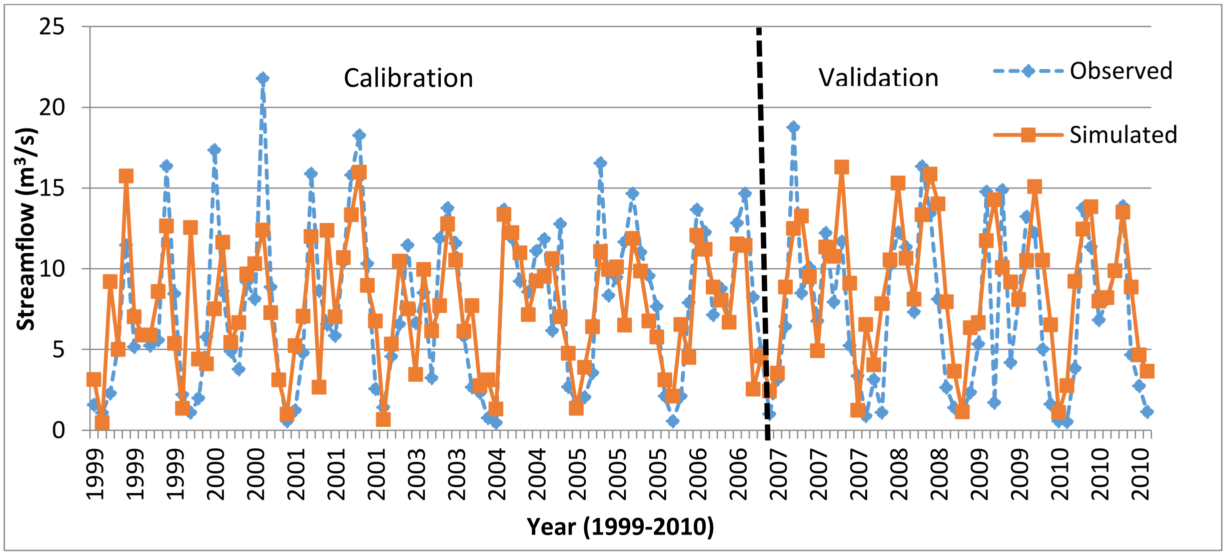

Figure 14: Simulated and observed monthly flow for calibration and validation period

The hydrograph for the validation period was given in figure 14, this figure shows the model overestimates the flow especially for dry season and underestimates pick flow and minimum flow. However, performance indicators show a good agreement between simulated and measured flow values for the validation period. These indicators show a good fit of the model with value of 0.71, and 0.56 respectively for R^2, and NS.

Generally studies in the different parts of Ethiopia and world confirms, the SWAT model has capability for simulating stream flow that correlated with observed values (Abbaspour, 2015; Anoh *et al*., 2017; Gokhan *et al*., 2017; Tibebe *et al*., 2017). The means for evaluating model performance in those studies were R^2 and NS, their values corresponds $R^2>0.6$, and NS >0.5. Similarly performance indicators for the current study found in the range of $R^2>0.6$, and NS>0.5 which confirms the model simulated values was at acceptable range for the catchment.

4.1.3 Transferring calibrated model parameters to Chichu River catchment

Predication of the runoff in ungauded catchment carried out via transferring calibrated model parameters from gauged catchment. This was done based on the HRU similarity, because of HRUs incorporates same characteristics of the land use, soil and slope, so expected to have similar hydrologic properties (Sangeeta & Rahatwal, 2017; Vincent Roth *et al*.,2017).

The result of the watershed characterization depicts, Walame River catchment delineated into five sub catchments. Thus, only sub catchment one had observed stream flow data on the daily basis and is the sub basin in which the model calibration and validation was carried out. So that the rest of the sub catchments (2, 3, 4, and 5) are ungauged and calibrated model parameters are required to be transferred. As described in the figure 15, Chichu River catchment delineated as sub catchment two, and calibrated model parameters were directly transferred into the sub catchment of the interest (Chichu River).

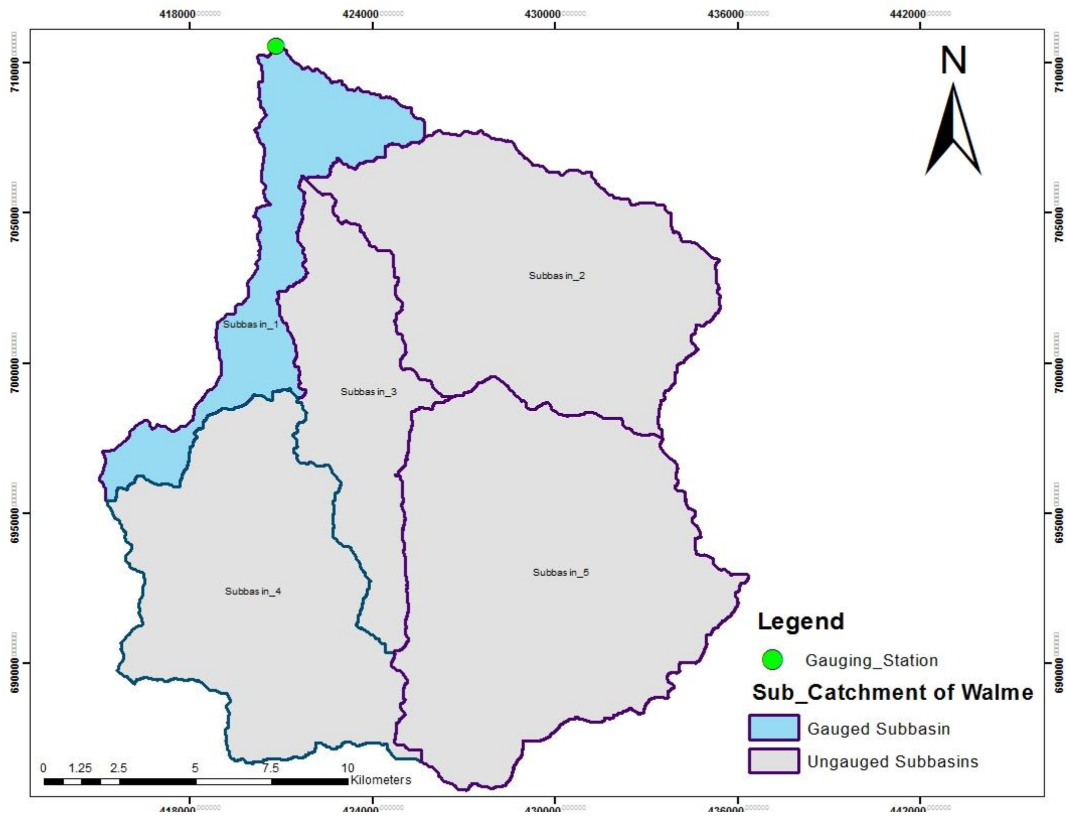

Figure 15: Gauged Walame River catchment and its Sub-catchments

Through transferring calibrated model parameters using gauged Walame River catchment; surface water resource estimation of the Chichu River sub-catchment was done based HRUs similarity. The HRUs similarity of the gauged and ungauged sub catchments were described in figure 16. This figure depicts, the catchment has clear similarity of HRUs that distributed spatially over in whole catchments. Thus, water resource components of the catchment were predicated successfully.

Similarly, surface water resource assessment study were done in some ungauged sub catchment of the Lake Tana basin (Tegegne & Young, 2015) by transferring calibrated SWAT model parameters from the gauged upper catchments of the basin based on HRUs similarity. Teso *et al*., (2015), predicated runoff yield through transferring calibrated parameters from Keleta River watershed (gauged) to Boru River watershed (ungauged) by using SWAT model based on the similarity of the hydro-metrological and physical characteristics.

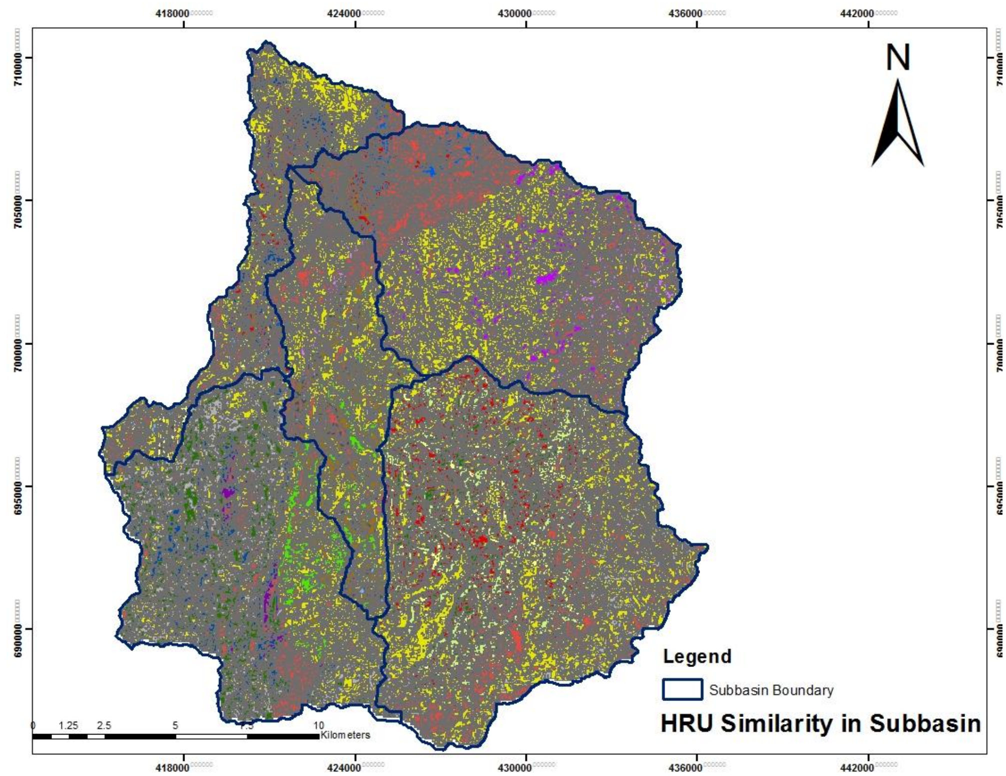

Figure 16: Hydrologic response unit similarity of the sub basin in Walame River catchment

4.1.4 Surface water resource of Chichu River sub catchment

SWAT model result was used to estimate water resource of the Chichu River catchment for the studied period. After writing back the final calibrated model parameters, the values that obtained from the calibration processes was used to simulate water resource of the catchment.

As showed in figure 17, the simulated result of the catchment founded to be related that of the measured values on annual basis. The annual rainfall, surface runoff (Sur_Q), lateral soil flow (Lat_Q), groundwater contribution (Gw_Q), evaporation and transpiration (ET),and potential evapotranspiration (PET) of the catchment over the investigated period (1999 to 2016) were 1285, 167.79, 227.31, 636.89, 208.8, and 481.2 respectively on annual basis in millimeter. Based on the catchment area (82.323 Km^2) of the Chichu River catchment, the total annual surface runoff of the catchment was estimated to be 13.81 MMC.

Due to the high infiltration and interception of the rainfall, agricultural and agroforestry based watersheds have little potential for runoff generation. Thus later soil flow contribution to the stream flow (Lat_Q) taken as surface water resource in the SWAT model (Inchell *et al*., 2013;

Anoh *et al*., 2017). In line with this, a total surface water resource of the catchment was estimated to be 32.53 MMC and a catchment's total water yield was 1066.17 mm.

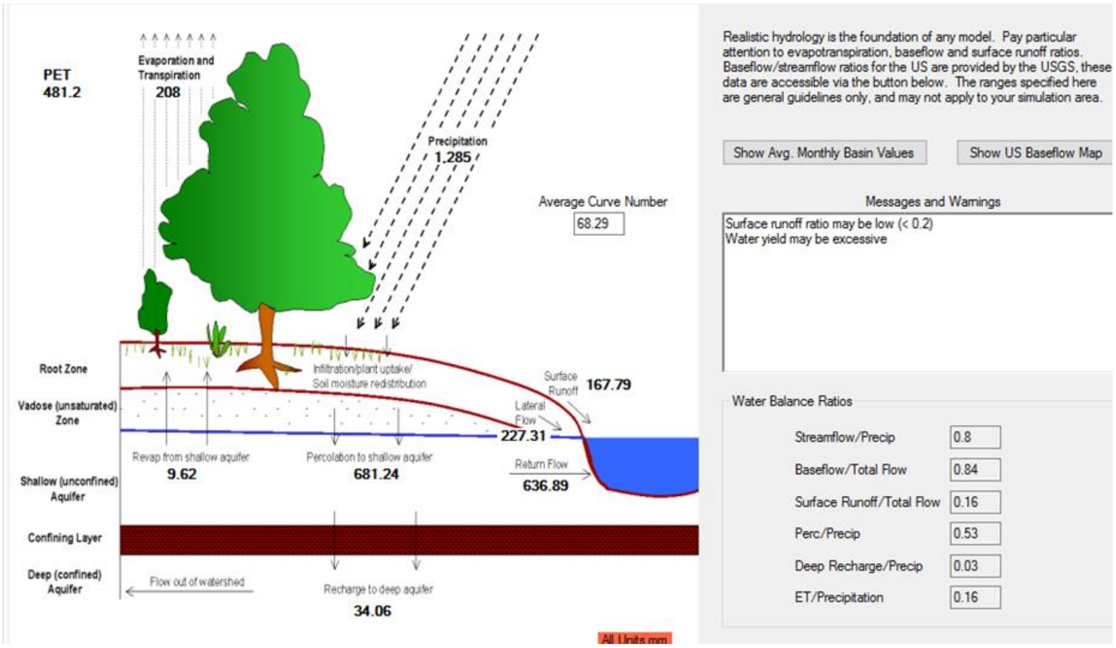

Figure 17: Water balance components of the Chichu River sub catchment

The water balance components of the catchment in the average annual values on monthly basis were given in figure 18.

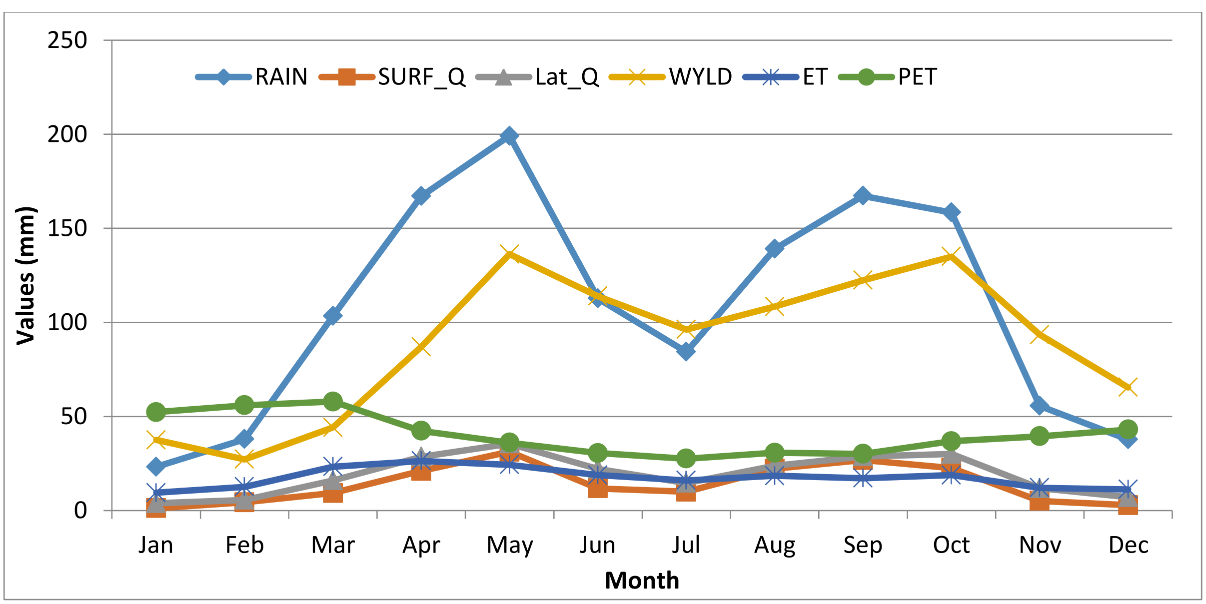

Figure 18: Average annual monthly values of the watershed, Chichu River catchment

Figure 18 infers; the water yield (WYLD), surface runoff (SUR_Q), and lateral flow (Lat_Q) correspond the rainfall (RAIN) trends of the watershed. Thus, the peak rainfall and corresponding high water yield appear form the March to June, and again the peak period occur starting from July and then it at the end of the November. The maximum values were observed during May (199.18, 136.3, 31.16, and 35.6 in mm respectively for rainfall, water yield, surface runoff and lateral flow) and followed by April, September and October.

The evapotranspiration (ET) and potential evapotranspiration (PET) of the catchment shows the seasonal variations, the maximum ET and PET occur during dry season (January to March) and show decrement following the rainy season (May to September).

Generally, Chichu River catchment has plenty water resources, which mainly controlled by the properties of the watershed. Thus, the catchments water yield is highly governed by the lateral and groundwater flow. This is may be the result of the land use, soil, slope and management conditions, which preclude high surface runoff potential.

4.2 Impact of wet coffee processing plant's effluent on water quality parameters

In study area all available wet coffee processing (WCP) industries were located proximate to Chichu River, this is due to the large quantity of water required for processing. In turn huge amount of the effluents was generated, and discharged to the receiving environment. As perceived via field observation, some of the industries have disposal pits which expected to reduce pollution effect on the receiving environment, but the observed disposal pits were not correctly constructed (Appendix B). Thus, generated huge amounts of untreated wastewater released into the river water and land surfaces during peak processing time, in turn aggravate pollution of the river water.

4.2.1 Physiochemical characteristics of the water quality parameters

From studied quality parameters, the examined physiochemical quality parameters average and standard deviation values were given in table 7.

Table 7: Mean values for studied physiochemical quality parameters in study area

S	SP	PH	EC μS/cm) (	Tu (NTU)	T (ºC)	DO	TDS	TSS
S1	USP	7.83±1.03^{a}	137.8±4.97^{a}	28.2±15.3^{a}	20.8±4.94^{a}	6.03±1.2^{a}	106.39±2.2^{a}	117.47±7.8^{a}
	ESP	4.26±0.8^{b}	2296.7±52.8^{b}	1020.83±57^{b}	29.97±2.21^{b}	1.02±0.2^{b}	2092.4±71.7^{b}	3781.2±24^{b}
	DSP	5.53±1.1^{c}	1697.9±20.2^{c}	658.5±40.2^{c}	20.87±1.16^{c}	1.69±0.5^{c}	1832.9±33.9^{c}	2851.7±60^{c}
S2	USP	7.21±0.54^{d}	189.5±2.81^{d}	143.27±4.17^{d}	18.59±1.59^{d}	4.47±0.7^{d}	158.63±3.95^{d}	151.23±3.21^{d}
	ESP	3.99±0.29^{e}	2301.3±90^{e}	1131.43±32^{e}	31.37±5.46^{e}	0.78±0.8^{e}	2175.4±9.01^{e}	3962.7±65.4^{e}
	DSP	5.07±0.55^{f}	1786.5±58.3^{f}	865±68.79^{f}	21.86±2.05^{f}	2.34±0.4^{f}	1986.57±7.4^{f}	2385.6±29.9^{f}
S3	USP	5.90±0.18^{g}	209.8±8.91^{g}	194±36.19^{g}	19.80±2.11^{g}	2.70±0.6^{g}	219.22±2.42^{g}	318.5±27.3^{g}
	ESP	3.85±0.31^{h}	2341.5±96.4^{h}	1210.6±73.8^{h}	24.05±3.11^{h}	0.23±0.4^{h}	2382.8±29.6^{h}	3864.8±63.7^{h}
	DSP	4.66±0.75^{i}	1816.4±44^{i}	893.23±48.7^{i}	23.24±2.49^{i}	1.47±0.6^{i}	2098.2±11.7^{i}	2448.2±82.8^{i}
S4	USP	5.52±0.59^{j}	241.5±17.3^{j}	208.23±69.4^{j}	25.06±2.26^{j}	1.5±0.73^{j}	246.47±18.5^{j}	395±16.22^{j}
	ESP	3.33±0.48^{k}	2385.5±52^{k}	1289.97±66.3^{k}	34.47±2.41^{k}	0.13±0.3^{k}	2417.23±25^{k}	4076.87±90^{k}
	DSP	4.03±0.5^{l}	1965.7±62.9^{l}	917.43±93.4^{l}	26.28±1.47^{l}	0.85±0.4^{l}	2146.07±15^{l}	3157.83±69^{l}

The units for parameters that depicted in table 7 were given in mg/L and otherwise their respective units stated. Mean and standard deviation values followed by superscript latters (a, b, c, d, e, f, g, h, i, j, k, and l) in each column represents there is significant ($p<0.05$) variations between sample site and points as analyzed via one way analysis of variance (ANOVA) (Appendix C). And shortening names of S, SP, USP, ESP, and DSP; are stands for sample site, sampling point, upstream sampling point, effluent sampling point, and downstream sampling point respectively.

As revealed in table 7, the evaluation of the physiochemical quality parameters at different sampling site and points indicates the USP of S1 the river water is at optimal quality status, but downstream river water quality parameters are largely impaired due to discharging of the coffee wastewater with large loads of physiochemical constituents.

The mean concentration of the all analyzed physiochemical quality parameters except pH and DO, were significantly ($p<0.05$) higher at the downstream site. Very low pH value (very acidic) (3.33±0.48) and much deteriorated DO (0.13±0.3 mg/L) were identified at the ESP of the S4. This depicts, the releasing of coffee wastewater has noticeable influence on physiochemical properties of the river water and the discharging of effluent from multiple processing plants on the downstream locations presents serious deterioration problem on the water quality. Each of the studied physiochemical quality parameters were discussed in the following sections:

4.2.1.1 Water pH

The pH of the water at all assessed sample sites and points shows significant variation ($p<0.05$) (appendix C). In line with this, in the upstream points of the S1 and S2, the pH value ranges from 7.21±0.54 to 7.83±1.03 is in the range of the natural water pH (6 to 8) for surface water (USEPA, 2011; WHO, 2017). While the effluent discharge points of all site exhibits very acidic pH nature, its values ranging from 3.33±0.48 to 4.26±0.8. The pH values in the downstream points of all sites shows little decrement that compared with ESPs, and its value found to be in this range (4.03±0.5 to 5.53±1.1). The mean values of pH for downstream sites were significantly acidic than maximum permissible limits. This represents, the coffee wastewater that discharged into river water contained more acidic properties. Thus the river water experiences quality problem and aquatic life may be hampered due to toxicity of the water to live in it.

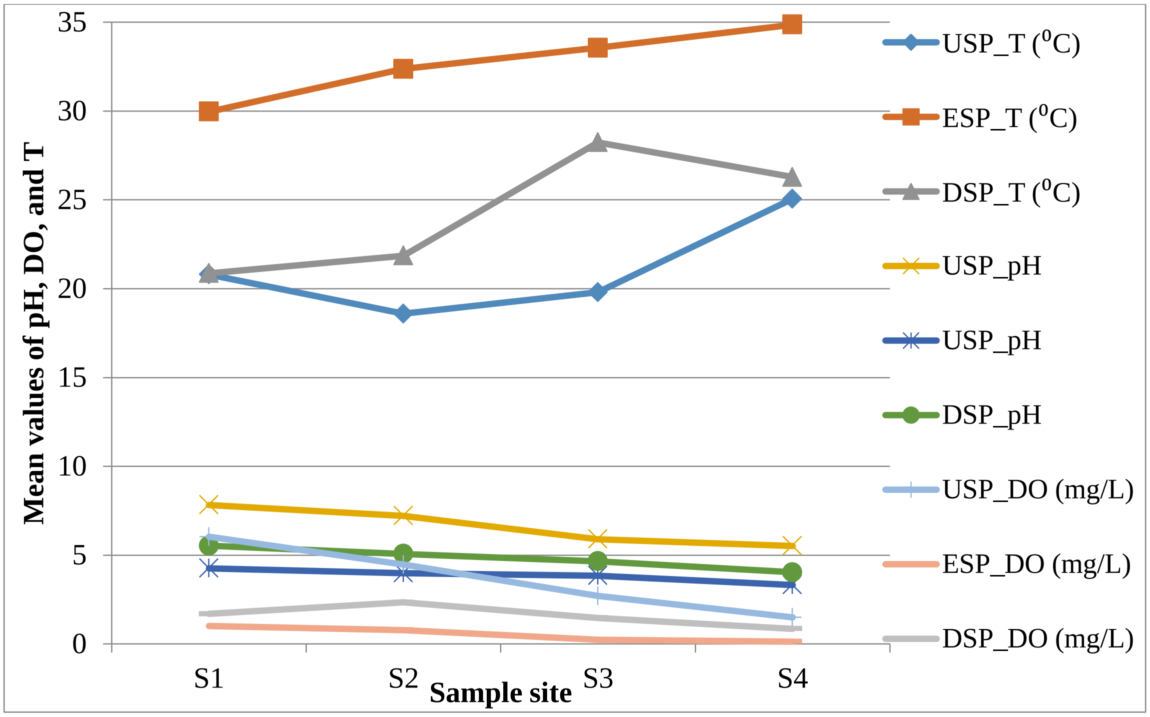

Figure 19: pH, T, and DO value variation in each sampling site and point in study area

Similarly the acidic pH value were reported by studies that conducted on the coffee processing wastewaters (Woldesenbet *et al*., 2014; Minuta & Jini, 2017). However, the lowest pH value (more acidic) nature of the receiving river water was observed in this study. This may be the result of using multiple processing stations in river water, poses pollution of the downstream river water due to discharging of huge effluent with acidic nature.

In all examined sites and points the value of pH is decreasing from S1 to S4; correspondingly, the value of pH ranges 7.83±1.03 to 5.51±0.59, 4.26±0.82 to 3.33±0.48, and 5.53±1.03 to 4.03±0.5 respectively for USP, ESP and DSP. In the USP of the S1 the observed pH value is significantly higher ($p<0.05$) that of the S4, this is may be the upstream river water are free from pollution effect of the effluents. But, the downstream sites the releasing effluents and residual constituents from series stations exhibits polluting situation on the river water. The examined pH at the ESP in all sites shows little variations; this might be result of similarity in nature of coffee bean and processing ways. The pH value in the DSP of each sites, higher than (less acidic), that of ESP (more acidic) this may be result of the natural self-purification of the river water from discharged constituents. But, this natural purification capacity of the Chichu River affected at the downstream site (S4), in which acidic nature of water examined.

Generally, the examined pH value at downstream sampling points is below the standards (6 to 9) of EEPA for surface water quality (EEPA, 1997); the USEPA standards for discharge of environmental pollutants to inland surface water (5.5 to 9) (USEPA, 2011) and standards for surface water quality for irrigation (6.5 to 8.4) (FAO, 2011).

4.2.1.2 Temperature

The result of this study for the water temperature ranges 18±1.19°C to 25.06±2.26, 24.05±3.11 to 34.47±2.41, and 20.87±1.16 to 26.28±1.47.47 respectively for USP, ESP and DSP. As it seen from table 7, observed temperature value shows significant ($p<0.05$) variation between sample site and points. The change in the temperature may be the result of the elevation range of the site and points; measuring duration of the sample; and the daily variation for sampling period. Regarding to the altitude, lowest mean temperature was recorded in the higher elevation sites (S1 and S2); this may be the fact of inverse relations.

The highest temperature (34.47±2.41°C) was observed at ESP of the S4; which shows the effluent discharge from processing plants exhibits pronounced temperature effect. The study conducted in Jimma Zone illustrates, the variations in the temperature from 15.5 to 19.4°C respectively for upstream and downstream sites (Dejen *et al*., 2015). Likewise, the studies that carried out in the coffee wastewater showed that, high temperature were reported in the effluent discharge points (Asrat, 2016; Minuta & Jini, 2017).

The result of the present study shows, the differences in the maximum value of temperature might be due to variations of ambient temperature of study areas and sampling period. In addition to that, recorded temperature at S4 significantly ($p<0.05$) higher than other sites (S1, S2 and S3), and lowest temperature were recorded at the USP of S2 (18.59±1.59°C) (figure 19). Normally except for the USP of the S1,S2 and S3 the observed temperature values are above the standards for the surface water quality to sustain biotic conation (USEPA, 2011). Since raised temperatures in the water bodies may result in facilitated microorganism’s activity, in turn the dissolved oxygen contents reduced from the required concentration.

4.2.1.3 Dissolved oxygen

The analyzing sample data for the dissolved oxygen in study area infer that, the maximum concentration of DO (6.03±1.19 mg/L) was measured in the USP of the Chichu River at S1; while the lowest DO (0.13±0.31 mg/L) value was detected at the downstream of the river of the ESP of S4. As depicted in figure 19, detected value of DO is decreased to the downstream; this may be the result of effluent discharge from multiple wet coffees processing plants and residual constituents form series plants. In all examined sites and points, DO value shows decrement; regarding sample sites DO shows a significant ($p<0.05$) decrease from S1 to S4 even for upstream sample points, whereas for sample points lowest DO concentration was observed in the effluent discharge and downstream sample points. And also, USP of the downstream site (S2, S3, and S4) show dwindling in the DO concentration; this might be residual constituents of effluents from other upper stations which present pollution effect on quality of river water and prompt oxygen is consummation during the decomposition of high organic matter.

At all, detected value of the DO at downstream sites (S2, S3 and S4) is much below the surface water quality standards of Ethiopia, WHO and USEPA, a minimum DO requires to support aquatic life 4-6 mg/L, 4.5-7.5 mg/L and greater than 5 mg/L respectively (EEPA, 1997; USEPA, 2011; WHO,2017).

Much deteriorated concentration of DO may be the result of the high loads of organic concentration, high temperature and increased acidity. Since DO level may fall, when temperature of water rises. Far minimum concentration of the DO was founded in this study, when compared with the reported result by Deselgen, (2018). This may be using multiple wet coffee processing industries in same receiving river water may result in the deteriorated DO concentrations, due to discharge of the huge effluents with high loads of the physiochemical and organic constituents.

4.2.1.4 Electric conductivity

The analyses of sample for EC reveals, the lowest EC (μS/cm) value was observed at the USP of the S1 (13.8±4.97) and the highest at the ESP of the S4 (2385.5±51.8). As represented in table 7 and figure 20, the values of EC showed significant ($p<0.05$) variation between sample site and points as analyzed via one way ANOVA (appendix C). This might be the EC of water depends on water temperature and dissolved ions contents, so that the trends in the EC is not uniform, but its values in effluent discharge point is higher for all investigated points; which followed by downstream sampling points.

The study conducted on characterization of coffee wastewater in Jimma Zone infer that, EC values exhibits variations ranging from 63.2 µS/cm to 871 µS/cm (Dessalegn, 2018) and 45 µS/cm to 1240 µS/cm (Dejene *et al*., 2015). Thus, higher EC value was observed in this study; this may be raised water temperatures and high total dissolved solids in the river water due to releasing coffee wastewater from serious stations.

EC of water is considered as rough indicators of water quality for many purposes, since it is directly related to the sum of the all ionized solutes contents and its value is used to estimate TDS. The result of this study depicts, except for the USPs the obtained EC value is above the surface water quality standards of Ethiopian which is 1000 µS/cm (EEPA, 1997). The high value of EC might be result of the decomposition of organic compounds during pulping and fermentation of the coffee pulp. Still, EC values immediately after effluent points (200m downstream) decreasing; thus EC values at S4 decreased from 2385.5±51.8 µS/cm (ESP) to 1905.1±62.92 µS/cm (DSP) (Table 7). The dropping in EC value at downstream points may be the result of dilution of coffee wastewater with river water, but per results of the current study only minimum decrement was observed (figure 20). Due to this the downstream river water is largely impaired, since the raised EC values may cause unsuitable of the water for drinking, agriculture and ecosystem survival. This excess amount of the EC may result in the salinity of the river water and in turn make downstream water unsuitable for beneficial uses. This finding was in constituent with studies done by (Woldesenbet et al., 2014; Tadesse & Alemayehu, 2016; Minuta & Jini, 2017).

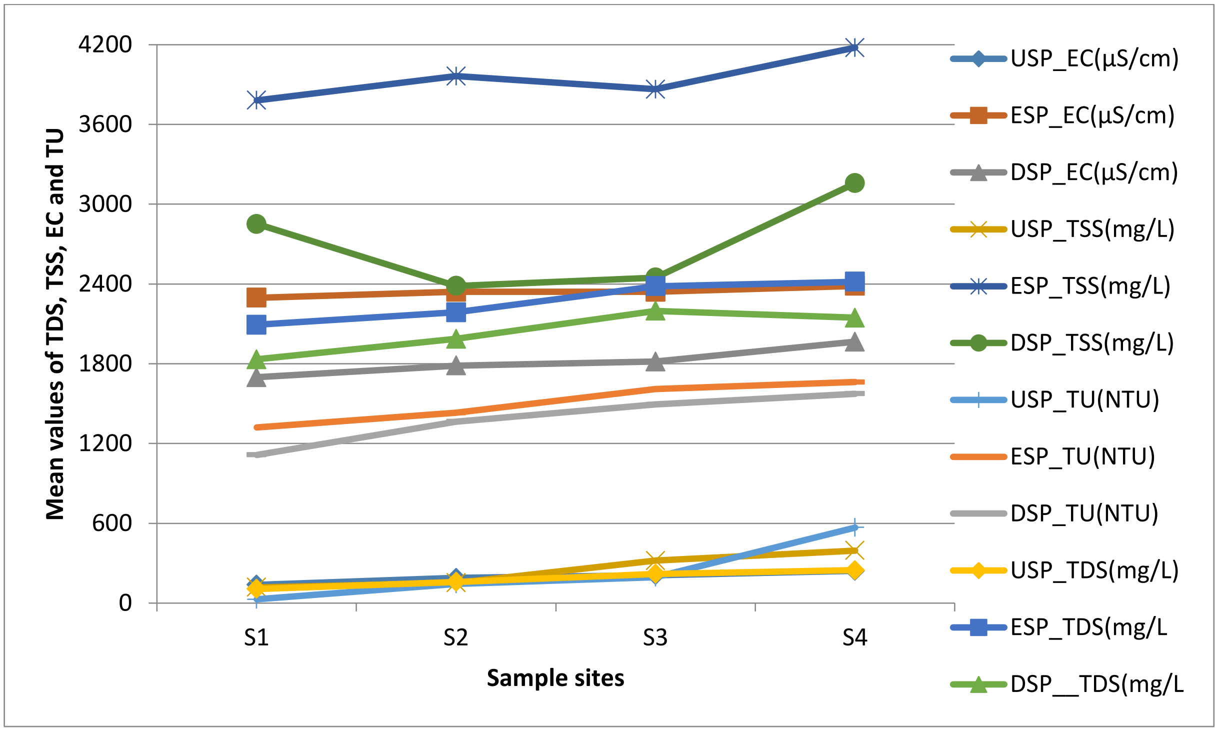

Figure 20: Variation in EC, TSS, TU, and TDS in each sample site and point in study area

4.2.1.5 Turbidity

As portrayed in table 7, turbidity for all sites and points shows great variation ranging from 28.2±15.3 (USP at S1) to 1320.83±57 (ESP at S1) and 568.23±69.4 (USP at S4) to 1661.97±66.3 (ESP at S4). Finding of this study infers; discharging of the coffee wastewater from multiple plants raise turbidity of the receiving water, in which water turbidity was increased immediately after receiving coffee wastewater that compared with upstream sample point. Even in upstream sample points of the S2, S3, and S4 high mean values of 143±4.17, 194 ±36.17, and 208.23±48.7 NTU were observed respectively.

As depicted in figure 20, releasing of coffee wastewater to surface water raises turbidity of the water. As result precluding light penetration to the water bodies, high turbidity of water may pose serious problem for photosynthesis of the aquatic life. In turn aquatic life highly in lack of light for sustains their lives. In addition, the increased turbidity of the water may not be preferable for agriculture, since crops need on average unescalated turbidity 5 NTU (FAO, 2011) and for domestic uses escalated turbidity is unsuitable. The finding of the this study corresponds studies that reported by Padmapriya *et al.*, (2013) and Kiran *et al.*, (2018). But high mean turbidity values were observed in this study, this may be result of using series wet coffee processing mills in Chichu River that emancipating untreated wastewater with huge contents of suspended materials.

4.2.1.6 Total dissolved solids

The detected TDS (mg/L) ranges from 106.39±2.18 to 246.47±18.5, 2092.4±71.7 to 2417.23±25.4, and 1832.9±33.9 to 2146.07±15.1 respectively for upstream, effluent and downstream points (table 7). Observed mean value of TDS for examined sample point shows significant ($P<0.05$) variations (appendix C). As described in figure 20, minimum TDS value was detected on the USP of S1, and raises for other DSPs even for upstream sample points of S2, S3, and S4. Higher values was recorded in the ESP of the all examined sites with maximum value of 2417.23±25.1 mg/L, while DSP exhibits significant ($p<0.05$) difference which compared with ESP of each site. This due to discharged effluent may be diluted via natural self-purification of the river water.

The identified a minimum and maximum values of the TDS were 106.39 and 2417.23 mg/L respectively, this result seems to be very high which compared to study that conducted by Minuta & Jini (2017) in Walame river, southern Ethiopia reported the range of TDS 198.24-411.5 mg/L. But study that conducted by Dejene et al., (2015), reports mean range of TDS for upstream and downstream site 73 to 246 mg/L and 349 to 9034 mg/L respectively. The variation in mean TDS value may be result of the natural river water conditions for salt ion concentration and coffee processing wastewater characters. At all, the obtained result for the downstream sites were above the surface water quality standards of the Ethiopia TDS<1000 mg/L (EEPA,1997) and using water from these source was at big questions for drinking, because mean value of the TDS < 600 mg/L (WHO, 2017) and agricultural (300-700 mg/L) (FAO, 2000) purposes.

4.2.1.7 Total suspended solids

The mean value of TSS in this study; 117.47±7.81 to 395±16.22 mg/L, 3781.2±24 to 4076.87±90.7 mg/L, and 2385.6±29.9 to 3157.83±69 mg/L were obtained respectively in USP, ESP and DSP of the sample sites (table 7). As depicted in the figure 20, higher TSS values were founded in effluent sampling points of the all site, this is due to discharged coffee wastewater consist large particles of the floating materials. As result obtained via one way ANOVA result (Appendix C), the measured TSS value in the upstream, effluent and downstream points were shows significant ($P<0.05$) variations. When S4 taken as reference site, the difference in the effluent (4076.87 mg/L) and downstream (3157.83 mg/L) points were 919.04 mg/L, this indicate that at the distance of 200m from the effluent discharge points the level of the TSS decreased by 29.1%, the reason may be natural self-purification of river water from discharged constituents but, until the obtained TSS level were maximum.

Similar to TDS, value of TSS raised to downstream of the river, even substantial change in values was obtained in effluent releasing points; 3781.2±24, 3962.7±65.4, 3864.8±63.7, and 4076.87±90 mg/L of TSS were obtained at ESP of S1, S2, S3, and S4 respectively. This evaluation shows, concentration of the TSS was increased to lower site that incorporates multiple wet coffee processing stations in series with Chichu River water (figure 20).

The obtained value of TSS were much larger (4076.87 mg/L) than that reported by Minuta & Jini, (2017) (414 mg/L), Dejene et al., (2015) (2504 mg/l) and Desalegn, (2018) (2260 mg/L), this might be result of using multiple wet coffee processing mills in same river that receive coffee wastewater from it. Evidently, average detected TSS value of this study was beyond the range put by Ethiopian surface water quality standards (50 mg/L) (EEPA), standards for pollutants discharge to inland surface water (100 mg/L) (USEPA, 2011). This high concentration of the solids in aquatic resource may lead to negative impacts, because the turbidity of water reduce light penetration in turn leads to decreased in photosynthesis.

4.2.2 Organic and nutrient load of the water and coffee wastewater

Table 8: Mean values for organic and nutrient parameters in the study area

S	SP	BOD_5	COD	NH_4^+-N	$P\text{-}PO_4^{3-}$	NO_3-N
S1	USP	3.55 ± 0.43^{m}	4.27 ± 0.66^{m}	0.90 ± 0.52^{m}	2.56 ± 0.56^{m}	0.77 ± 0.3^{m}
	ESP	509.17 ± 27.6^{n}	1907.2 ± 36.1^{n}	13.57 ± 0.8^{n}	11.0 ± 1.18^{n}	14.37 ± 0.8^{n}
	DSP	241.77 ± 53.4^{o}	1697.17 ± 58.7^{o}	11.47 ± 1.53^{o}	10.93 ± 2.01^{o}	9.81 ± 0.66^{o}
S2	USP	15.10 ± 2.19^{p}	32.43 ± 1.40^{p}	0.84 ± 0.18^{p}	2.76 ± 0.92^{p}	0.95 ± 0.11^{p}
	ESP	635.67 ± 68.9^{q}	2038.83 ± 82.6^{q}	14.70 ± 0.82^{q}	16.93 ± 2.38^{q}	19.30 ± 1.8^{q}
	DSP	362.40 ± 55.7^{r}	1914.40 ± 90.3^{r}	14.97 ± 0.57^{r}	13.83 ± 1.62^{r}	11.31 ± 0.5^{r}
S3	USP	45.80 ± 11^{s}	64.53 ± 8.69^{s}	1.72 ± 0.56^{s}	5.31 ± 0.73^{s}	1.24 ± 0.24^{s}
	ESP	757.90 ± 73.6^{t}	2091.83 ± 91.7^{t}	16.27 ± 0.8^{t}	22.70 ± 1.54^{t}	19.00 ± 2.1^{t}
	DSP	537.67 ± 77.84^{u}	1839.50 ± 59.7^{u}	15.70 ± 1.75^{u}	14.93 ± 1.75^{u}	12.13 ± 0.6^{u}
S4	USP	63.10 ± 8.55^{v}	92.97 ± 17.48^{v}	1.08 ± 0.17^{v}	12.70 ± 1.81^{v}	1.90 ± 0.72^{v}
	ESP	799.37 ± 71.63^{w}	2147.33 ± 50.4^{w}	20.80 ± 2.55^{w}	34.73 ± 7.40^{w}	23.02 ± 4.0^{w}
	DSP	631.43 ± 73.58^{x}	1963.07 ± 63.5^{x}	17.50 ± 0.98^{x}	19.67 ± 1.30^{x}	17.5 ± 0.62^{x}

The units for studied parameters that depicted in the table 8, are given in mg/L and their shortening names stands for biological oxygen demand (BOD), chemical oxygen demand (COD), ammonia nitrogen (NH_4^+-N), phosphate (PO_4^{-3}), and nitrate (NO_3-N). The mean and standard deviation values followed by different superscript latters (m, n, o, p, q, r, s, t, u, v, w, and x) in each column represents one way analysis of variance (ANOVA) (appendix C), which indicates there is significant ($p<0.05$) variations between sample site and points.

4.2.2.1 Biological oxygen demand

The examined BOD_5 value in this study ranges from the minimum concentration at the upstream of the S1 (3.55±0.43 mg/L) to the maximum at effluent discharge points of the S4 (799.37±71.63 mg/L). Like other studied parameters, one way ANOVA test for the BOD_5 values shows significant ($p<0.05$) differences between sample site and points. As displayed in figure 21, the concentration of the BOD_5 raise from the upstream to effluent and sharply decreased from effluent point to downstream sample points. This shows that the coffee wastewater contains huge amount of the organic materials to consume large amount of the oxygen and present polluting effect to the receiving water bodies.

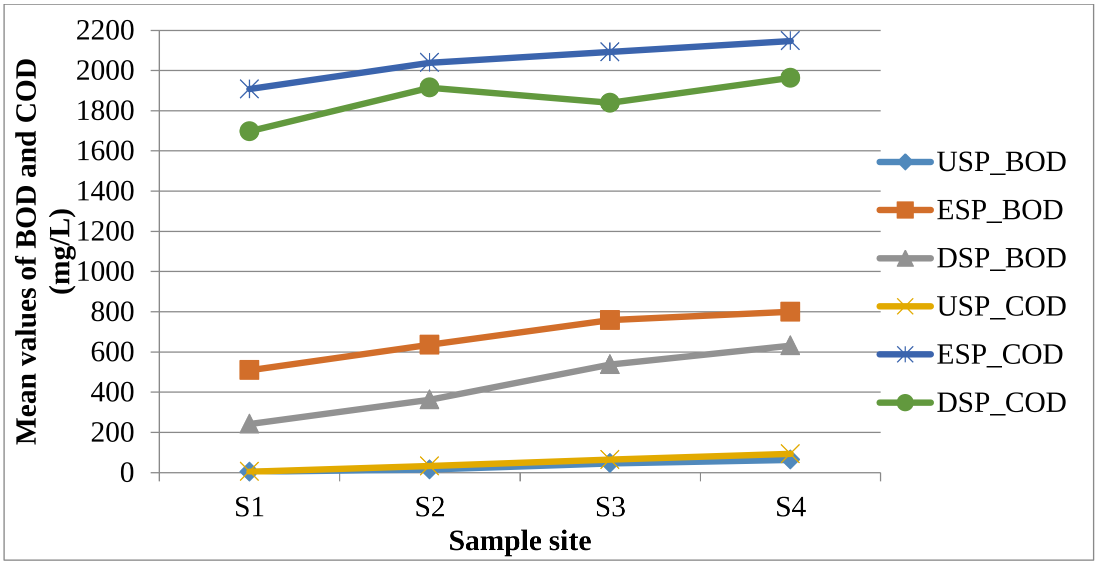

Figure 21: Mean examined values of BOD and COD at sample site and points in study area

As it seen from the figure 21, the BOD value shows sharp rise in the effluent sampling points and a maximum a value was detected at this points. As sited by Desalegni, (2018), the organic substance diluted in the wastewater breakdown very slowly via microbial activity by using oxygen from the water. But DO contents were reduced; demand for oxygen to breakdown organic material in the wastewater exceeds the supply, in this way anaerobic conditions created. After effluent entered water body, the concentration of the BOD slowly decreased at some extent to the downstream points that compared with effluent points. This might be the result of the dilution of the discharged wastewater within water, but it evident that the wastewater from multiple wet coffee processing plants impacted downstream water bodies.

The effect of coffee wastewater on the BOD, COD and DO were evident, which consume much oxygen and result in death of the aquatic life due to lack of the oxygen. Thus, lack of the oxygen in the water bodies pave ways for proliferation of the unwanted microorganisms, attracting files and other insects, and making the water undesirable for drinking and poses additional costs of treatment..

The finding of this study for BOD_5 were in constituents with result that reported by Dessalegn, (2018). However, value was considered to be minimum which compared with study reported by Dejene et al., (2015), a maximum of 2967 mg/L BOD was detected at the effluent point. Generally, it is evident that discharging of the untreated coffee wastewater poses pollution problem on the receiving water bodies.

4.2.2.2 Chemical oxygen demand

The mean measured values of the COD shows similar trend with BOD, in which its concentration were minimum at the upstream of the S1 (4.27±0.66 mg/L), and the maximum at the effluent discharge points of the S4 (2147.33±50.04 mg/L) (Table 8). The raising of the COD to the downstream sites and points may be the impact of the effluent discharge from the multiple wet coffee processing mills on the receiving water courses (Figure 21). This is also the result of the degradation of the soluble compounds in coffee wastewater during fermentation of the pulp and mucilage, which indicates increment in chemical oxygen demanding waste and presence of the organic matter consumes the oxygen.

The examined values of the COD depicted that, the effluent and downstream point's exhibits larger value; however when it compared with other studies that conducted before much lower value was observed. Desalegn, (2018), reported a maximum COD values at effluent sample site (7200 mg/L) and a minimum values were detected at the upstream site (64 mg/L) in his study. The finding of this study constituents in the range (18.5 mg/L-3244 mg/L) that reported by Dejene et al., (2015). But the detected COD value were maximum when it compared with the result reported by Minuta & Jini, (2017).

Generally, it was evident that wet coffee processing wastewater raise the COD of downstream water bodies. The comparison COD values for the upstream, effluent and downstream points show that a much larger values were obtained at the effluent point, followed by the downstream points. And the least values observed at the upstream of the S1, which portrays the upstream water quality is not deprived pollution effect of the coffee wastewater.

4.2.2.3 Nitrate, phosphate and ammonia

Investigated nutrient parameters had direct relation to water quality, this mainly eutrophication of the water bodies as result of the excess nutrients. The result for all those parameters shows, their value were very low or at optimum condition for the upstream sites and the maximum values were recorded at the effluent and downstream points (Table 8). The measured values for NO_3-N, PO_4^{3-} and NH_4^+-N are 0.77±0.30 to 23.02±4 mg/L, 2.56±0.56 to 34.73±7.40 mg/L, and 0.84±0.18 to 20.80±2.55 mg/L respectively. As described in figure 22, the mean values of nutrient parameters exhibits significant variation in sample site and points, as tested by one way ANOVA a significant difference ($p<0.05$) were observed within and between sample site and points (appendix C).

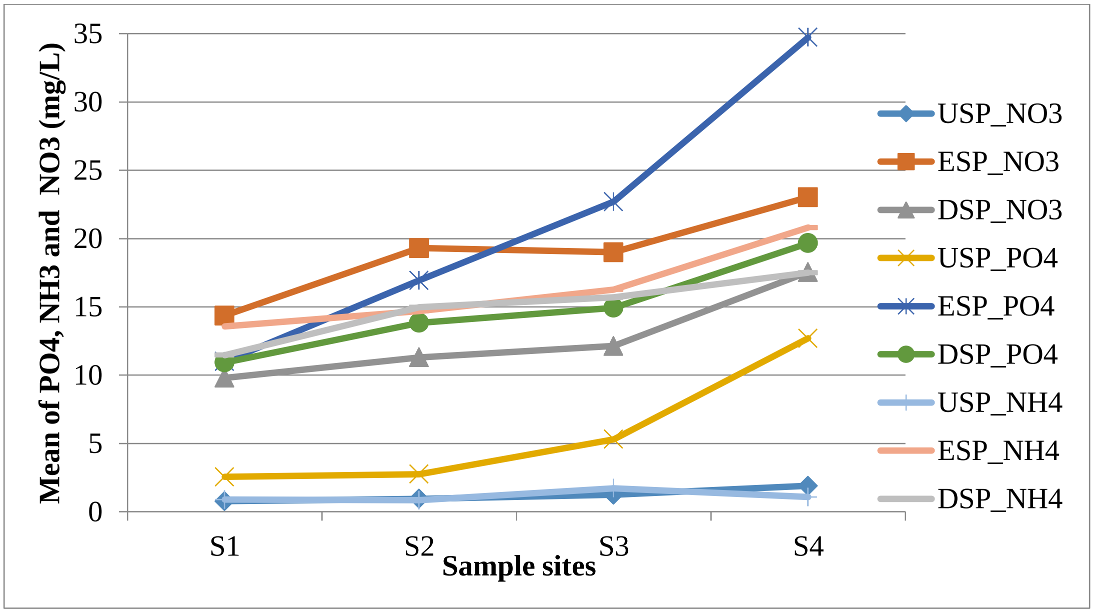

Figure 22: Mean concentration of nitrate, ammonia and phosphate in study area

As it depicted in figure 22, the concentration of the NO_3-N, PO_4^{3-} and NH_4^+-N were rises for ESP and DSPs. And also, sample sites shows increased concentrations from S1 to the S4. This indicates, upstream river water is not polluted via effect of the coffee wastewater; but effluent discharged point's exhibits serious water quality problem. DSPs shows slight decrement in concentration that compared with ESP, this might be self-dilution of the water from the discharged wastewaters. However, this natural capacity was highly disturbed via the releasing of the untreated coffee wastewater from the multiple processing plants.

Maximum concentration of NO_3-N (23.02 mg/L) were observed at effluent discharging points of S4 and followed by other prior sites, this may occur as result of the deamination of the ammonium nitrogenous material which oxidized to nitrate via microbiological actions (USEPA, 2000). But, lowest values of NO_3-N were recorded at upstream and downstream points. The recorded NO_3-N concentration was in the constituents with result that reported by

Deselgen, (2018); and Dejene et al., (2015) they point out the NO_3-N concentration in range from the non-detected value to 26.9 mg/L and 0.37 to 32.7 mg/L respectively.

Maximum concentration of PO_4^{3-} were recorded in this study ranges from 2.56 to 34.73 mg/L when it compared with studies that reported by Minuta & Jini, (2017), they reported PO_4^{3-} values on the range 2.12 to 3.8 mg/L. This may be a result of using multiple wet coffee processing plants on same the receiving river which dispose their wastewaters into it without treatment. But, finding is related to the study that done by Dejene et al., (2015), who reported 18.5 mg/L of PO_4^{3-} mg/L. In contrast, the acceptable concentration of the PO_4^{3-} a concern for plant growth, but current study identified higher concentrations of the PO_4^{3-} at downstream sites. When it compared with acceptable range that put by USEPA, (2011) and FAO, (2000), the average downstream concentration were three and seven fold much higher than the ranges respectively.

Generally the evaluation of the nutrient values shows, the upstream site (S1) and points' exhibit less affected by discharge of coffee wastewater; but the downstream sites was highly polluted due to the nutrient enrichment. This may lead to the pollution and eutrophication of the downstream water resources in turn put the aquatic life in big terror, makes unsuitable water for domestic and livestock uses, and adds addition costs for intensive treatment.

4.3 Evaluation of the quantity of the polluted surface water

The amount of the polluted water quantified based on the quantity of the water that required for processing in each processing industries per day. According to the Dejene et al., (2015), on average 147 m^3 water required per day for processing, but the quantity of the water required may increase depending on the size and quantity of the coffee to be processed. Thus, by considering this into account 200 cubic meters were used for estimating amount of the water that directly polluted through processing plants. The total amount of water required for processing period was 0.6 MMC. Since the wet coffee processing industries not consume water, but it discharge polluted wastewater to the catchment (Padmapriya *et al*., 2013). Thus, this significant quantity of the catchment's water was polluted each year and the recovery potential of the river water from the discharged coffee wastewater is highly reduced. This was indicated that, the downstream surface water resources of the catchment were indirectly polluted.

As depicted in the Figure 18, the surface water (Sur_Q) for the peak processing season (October, November, December and January) corresponds 12. 48 mm, 5.10 mm, 2.80 mm, and 1.20 mm respectively on the average monthly basis. In this peak season of the processing the catchment has 1.76 Mm^3 surface water resources and 0.6 MMC water was utilized for processing (washing, pulping and fermentation) period. Thus, 45 percentage of the catchment's available surface water resource were directly polluted during this season. Thus, the releasing of untreated coffee wastewater from multiple wet coffee processing industries to the catchment result in polluting surface water resource of the catchment directly. This might compromise the sustainability of wet coffee processing plants since the benefit that gained from the industries were compromising the environmental quality of the catchment.

Generally, as it was seen in this section the surface water resource of the Chichu River catchment were polluted significantly, which required immediate action to minimize the rate of pollution of the water. In turn the downstream water quality was deteriorated, which preclude the use of the river water from these sources for drinking, agricultural and environmental uses.

4.4 Suitability of the downstream water quality for beneficial uses

Table 9: Examined value and permissible limits for studied quality parameters

Parameters	Sample Site 1			Sample Site 2			Sample Site 3			Sample Site 4			Standards					
													WHO	FAO			USEPA	EEPA
	USP	ESP	DSP	USP	ESP	DSP	USP	ESP	DSP	USP	ESP	DSP		Su	Mo	Se		
pH	7.83	4.26	5.53	7.21	3.99	5.07	5.90	3.85	4.66	5.52	3.33	4.03	6.5–8.5	6.5 – 8.4			6.5-9	6.5–9
EC	137.8	2296.7	1697.5	189.5	2301.2	1786.5	209.6	2341.5	1816.4	241.5	2385.6	1905.2	1500	< 700	>700	<1000		1000
TU	28.2	1021	658	143	1131	865	194.1	1210	893	208.2	1289	917.43	5	5			5	-
T	20.8	29.9	20.9	18.6	32.37	21.	19.8	33.6	28.2	25.06	34.9	26.28	?15	4.4-18.3			-	-
DO	6.03	1.02	1.69	4.47	0.78	2.34	2.70	0.23	1.47	1.50	0.13	0.85	4.5-7.5		-	-	6.5	-
TDS	106.4	2092.42	1832.90	158.63	2187.40	1986.57	219.22	2382.83	2198.20	246.47	2417.23	2146.07	<600	<450	450-2000	>2000		1000
TSS	117.5	3781.2	2851.7	151.23	3962.7	2385.6	318.5	3864.8	2448.2	395	4176.87	3157.83	50	-	-	-	1000	-
BOD	3.5	509	241	15.4	635.6	362	45.80	757	537	63.10	799.	631.43	2-5	8	-	-	60	60
COD	4.3	1907.20	1697.17	32.43	2038.83	1914.40	64.53	2091.83	1839.50	92.97	2147.33	1963.07	10	-	-	-	250	250
NH_4^+	0.9	13.6	11.7	0.84	14.70	14.9	1.72	16.3	15.7	1.08	20.8	17.50		0 – 2			5	5
PO_4^{-3}	2.7	11.0	10.9	2.76	16.93	13.8	5.31	22.7	14.9	12.70	34.7	19.67	-	0 – 2	-	-		0 -2
NO^-_3	0.7	14.4	3.81	0.95	19.30	4.31	1.24	19.0	5.13	1.90	23.0	6.55	50	< 5	5-20	> 30		<20

Source: Current Study and different organization (EEPA, 1997; FAO, 2000; USEPA, 2011; WHO, 2017)

Except Su (suitable), Mo (moderate) and Se (severe), the acronym used in Table 9, were given in table 7 and 8. Utilization of the surface water for beneficial uses (agriculture, domestic, and environment) required their respective quality levels, this level may be governed by the physiochemical quality of the water. As described in the table 9, all examined water quality parameters have their level in each sample site and points. Consequently; based on quality status of the river water that determined in the current study and requirements (standards) of the each beneficial uses, fitness of the river water were evaluated.

Based on this evaluation and as per described in table 9 results, the USP of S1 river water is fitted for domestic, agriculture and environmental uses. However, water quality of river especially during peak wet coffee processing period is not suitable for agriculture, domestic and environmental requirements. Since the pupils in study area directly utilized water for different purposes from the river, they may be affected due to using impaired water. This problem more pronounced in downstream site (S4), when it compared with DSP of the S1, water quality parameters at this point (DSP of the S4); exhibit significant ($p<0.05$) change in the quality status based on investigated parameters (table 9).

It was observed that, pH for S1 ranges from 5.53, 7.83 and S4 it ranges from 4.03-5.52, respectively for the USP and DSP (table 9). Based on available standards, the downstream water during this period was not suitable for drinking (pH 6.5–8.5) (WHO, 2017), agriculture (pH 6.5 – 8.4) (FAO, 2000) and environment (pH 6.5-9) (EEPA, 1997; USEPA, 2011). Similarly, study reported by Tadesse & Alemayehu, (2016), and Dejen et al., (2015); acidity of the receiving water bodies raises and preclude its fitness for uses.

Temperature of the water may be varied spatial and temporal, but noticeable change was recorded in the DSP of the S4 (26.8 $^{\circ}$C), when it compared with DSP of the S1 (20.6 $^{\circ}$C). Using water from this source is not suitable for agriculture (4.4-18.3 $^{\circ}$C) and domestic uses (<15 $^{\circ}$C) (Table 9). Based on EC, turbidity, TSS, and TDS; again water quality of the river is out of the standards for beneficial uses. And obvious changes were obtained at DSP of the S1 and S4 (table 9), coffee wastewater in receiving water bodies may add stress of the pollution by raising concentrations of physiochemical constituents.

Organic loads (BOD and COD) of the river water at upstream sites were fitted for the agriculture, domestic and environment (table 9). But, values sharply rose for downstream sites and make the river water unsuitable for the beneficial uses during this period, and don’t meet the requirement 250 mg/L of USEPA, (2011).

In addition nutrient load of the river water is important to evaluate its fitness, based on determined values for nitrate, ammonia and phosphate (table 9), quality parameters shows water at some extent may be used for agriculture, but it may affect sustained use for aquatic life. This is due to nutrient parameters were responsible for eutrophication of the water bodies, in turn growth of the unwanted plants may be increased and as result the life of the vulnerable aquatic life disrupted. Study that conducted by Deselgen, (2018), infer that the increased nutrient concentration in the surface water may resulted in hampering the living service of the water for aquatic life. But at the optimum level these nutrients were vital to those lives.

Dissolved oxygen concentration in each of examined sites and points were inferring a clear change (table 9), this variation may be effect of the effluent. The detected DO level at USP of S1 was within range for the domestic (4.5-7.5 mg/L) and environmental uses (6.5 mg/L) as per standards. DO concentration were decreased for other downstream sites, in turn made water unsuitable for the beneficial purposes.

Generally, overall evaluations of the water quality in the downstream (S3 & S4) sites for all investigated quality parameters were above standards of different legislative bodies for respective beneficial uses. Especially downstream sites preclude using of water from this source for drinking, agriculture, domestic, and aquatic life to be sustained. Studies that reported by (Dejen et al., 2015; Minuta & Jini, 2017; Dessalegn, 2018) , infers coffee wastewater that discharged from wet coffee processing stations affect the physicochemical properties of the receiving water, this may result in precluding using of water for intended purposes and may poses health problem on the neighbor pupils. As result return obtained from the industries may be compromised, unless coffee wastewater treated before discharged into the receiving environment.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Water quality and quantity assessment was one of the important tasks for better planning and management of the scarce resource. Chichu River catchment surface water resource was estimated via SWAT model. The result shows, eight parameters are sensitive to the model; GW_DELAY.gw and SOL_AWC.sol are most sensitive. Performance indicators for calibration and validation period shows, good fit of which R^2=0.69, NS=0.53 and R^2=0.71, NS=0.56 respectively. Since the catchment is ungauged, the calibrated parameters from gauged Walame River were used to estimate water resource. The simulation result reveals, the annual surface runoff and total surface water resource corresponds 13.81 and 32.53 Mm^3 respectively. And catchment's water yield is 1066.17 mm, which indicates Chichu River catchment has excessive water resource potential and considered as one of the highland catchments in Rift Valley Lake basin that contribute huge amount of flow to the Gidabo watershed.

The current study area is one of the prominent areas for coffee production and a huge amount of the coffee produced each year via wet coffee processing methods and generate enormous amount of the coffee effluents. This generated wastewater was directly discharged into the river water, in which poses water quality deteriorations and compromise the benefits that gained from it. To evaluate these effects twelve water quality parameters were examined in four sample sites, and then samples were collected from twelve sampling points. The sample data were analyzed via onsite and laboratory assessment, pH, EC, turbidity, DO, and temperature analyzed onsite; while TSS, TDS, BOD, COD, $N\text{-}NO^{3-}$, PO_4^{-3}, and $N\text{-}NH_3$ examined at the laboratory. The result of analysis reveals, effluents from the wet coffee processing stations has huge impacts on the investigated water quality parameters. Very acidic pH (3.3-5.52), much depleted DO(0.13-1.5 mg/L); high organic load of which BOD(63.1-799.5 mg/L), and COD(92.97-2147.33 mg/L); huge concentration of TSS (395-4176.87 mg/L), TDS (246.47-2417.23 mg/L) and TU (208.2-1289 NTU); high nutrient load of which NH_3 (1.08-20.8 mg/L), PO_4^{3-} (12.7-34.73 mg/L) and NO^-_3 (1.9-23.02 mg/L) were obtained for downstream site (S4). When it evaluated with upstream site (S1), the result that observed at S4 shows significant change ($p<0.05$) for all examined water quality parameters. This infers, the effluents that released from wet coffee processing stations have pronounced pollution effect on the downstream sites. Thus except for the upstream sites, all examined physiochemical parameters in the downstream sites were deviated from the quality standards that putted by recognized bodies. In turn the water resources of the river at the downstream site were unsuitable for the drinking, agriculture and survival of the aquatic life and whole environment during peak processing time.

The observed pollution effect of the effluents on the river water quality parameters were noticeable, the impairing of these parameter's result in direct pollution of the water. Based on the amount of the water required per day for each processing stations, the total quantity of the surface water that directly polluted via discharge of the coffee wastewater was assessed. The finding of the study shows, from the total available quantity of the surface water (1.76 MMC) for the peak processing period (September to January) approximately 0.6MMC available surface water resources are polluted directly. These vital resources are polluted in each processing seasons, unless immediate action were taken the pollution profile of the Chichu River catchment are at alarming rate due to immense effluents from multiple wet coffee processing mills.

Generally; Chichu River catchment has plenty water resources that used for drinking, domestic, agriculture, and industries by local pupils. And also, available water resources used for ecosystem and aquatic life sustain. But these vital resources were under risk of the pollution due to the indiscriminate discharge of the effluents from the multiple wet coffee processing plants.

5.2 Recommendation

Based on the finding of the study, the following recommendations were set-forth. As investigated in this study; Chichu River catchment has plenty water resources, but a significant proportion of this water is highly polluted, such that the concerned government bodies and NGOs should develop mechanisms for water resource planning and management. Since, the surface water quality and quantity of the catchment was examined in the current study; further study shall be done focusing on the quality and quantity of groundwater resource and demand assessment in the catchments.

In order to minimize the effect of pollution from wet coffee processing, efforts should be made to develop effective methods for coffee waste management. Creating awareness for the involved stakeholders on the risk of the indiscriminate release of the effluent shall be made through local EPA offices. And also, the processing mills should only be functioned after environmental impact assessment and be subjected to relevant authorities for continuous monitoring. Thus, building environmentally sustainable economy and using the technologies that complies with environment were indispensible.

The concerned government bodies shall also expected to critically follow whether the wet coffee processing industry owners were implementing the regulations (coffee quality control and transaction), and pollution protection proclamations (to provide for coffee quality control and marketing). They shall be required to construct standard wastewater stabilization ponds in order to treat effluent before released into receiving environment. The industries shall adopt water-recycling system generated from pulping and washing in order to reduce the wastewater generation. Standards shall be put by recognized bodies for coffee effluents to be discharged into receiving environment. Further detailed studies shall be done on coffee wastewater organic, inorganic, chemical and biological compositions in order to determine effective technological treatment options, and its energy potential.

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APPENDICES

Appendix A: Collected instruments, onsite and laboratory assessment of the quality parameters

Figure a 1: Collected instruments and onsite measurement of the selected quality parameters

Figure a 2: Laboratory assessment of the water quality parameters

Appendix B*:* Observed images from the current study situation, Chichu River Catchment

Figure a 3: Improperly constructed disposal pits and its discharge into receiving environment

Figure a 4: Impacts of the effluent discharge on the Chichu River water

Figure a 5: Constructed pipes to discharge effluent and its effect on Chichu River quality

Figure a 6: Impacts coffee wastewater on the receiving environment (land surface)

Appendix C: Table a 1: One way Analysis of the Variance for examined quality parameters

		Sum of Squares	df	Mean Square	F	Sig.
PH	Between Groups	4.324	3	1.441	0.696	0.0048
	Within Groups	16.555	8	2.069		
	Total	20.879	11			
EC	Between Groups	33972.497	3	11324.166	0.014	0.0012
	Within Groups	6293788.174	8	786723.522		
	Total	6327760.672	11			
TU	Between Groups	340793.729	3	113597.910	6.040	0.019
	Within Groups	150466.676	8	18808.335		
	Total	491260.405	11			
T	Between Groups	44.958	3	14.986	1.304	0.018
	Within Groups	91.923	8	11.490		
	Total	136.881	11			
DO	Between Groups	8.232	3	2.744	0.857	0.049
	Within Groups	25.619	8	3.202		
	Total	33.852	11			
BOD	Between Groups	110012.717	3	36670.906	0.331	0.003
	Within Groups	885041.375	8	110630.172		
	Total	995054.092	11			
COD	Between Groups	60520.164	3	20173.388	0.017	0.007
	Within Groups	9576503.020	8	1197062.877		
	Total	9637023.183	11			
TSS	Between Groups	314772.332	3	104924.111	0.029	0.001
	Within Groups	28628468.297	8	3578558.537		
	Total	28943240.629	11			
NH3	Between Groups	31.896	3	10.632	0.146	0.009
	Within Groups	581.782	8	72.723		
	Total	613.677	11			
PO4	Between Groups	336.468	3	112.156	1.592	0.0026
	Within Groups	563.425	8	70.428		
	Total	899.892	11			
NO3	Between Groups	26.254	3	8.751	0.098	0.006
	Within Groups	713.431	8	89.179		
	Total	739.685	11			
TDS	Between Groups	382449.905	3	127483.302	0.066	0.046
	Within Groups	15486749.512	8	1935843.689		
	Total	15869199.416	11			

Appendix D: Average monthly rainfall of the Dilla, Bule and Kebedo stations

Table a 2: Average monthly rainfall (mm) of the Dilla station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	19.80	87.80	272.30	161.30	111.50	93.10	149.00	220.30	203.30	85.50	58.40	65.11
1998	85.20	115.07	129.70	197.90	173.70	145.80	107.50	155.20	121.30	120.70	96.70	101.31
1999	54.10	77.00	146.75	194.75	135.60	92.60	42.70	142.90	204.80	130.50	79.30	67.70
2000	42.30	93.10	138.29	157.98	228.23	174.90	168.98	196.98	183.46	208.49	120.76	78.67
2001	59.30	109.48	157.26	209.11	72.40	145.30	153.60	197.10	112.66	131.34	99.17	81.43
2002	49.50	67.30	146.40	164.20	82.00	141.80	95.00	90.20	70.80	115.70	137.10	98.70
2003	22.10	35.80	109.60	194.75	228.23	174.90	67.30	128.00	95.40	22.20	87.30	37.98
2004	41.60	39.50	113.00	94.40	73.70	63.40	126.00	70.00	112.20	45.40	44.30	18.91
2005	55.40	27.50	246.20	63.70	76.90	95.90	151.59	183.40	58.60	4.00	15.50	61.01
2006	15.50	51.40	151.10	206.20	158.40	151.40	53.70	159.50	130.30	292.10	82.00	39.40
2007	35.50	10.50	95.20	149.80	340.20	164.50	83.20	276.00	212.20	193.30	54.50	15.70
2008	10.50	20.70	164.80	198.50	213.90	85.10	143.80	89.00	161.70	154.30	74.60	16.30
2009	22.30	40.80	39.50	207.20	134.60	72.00	25.90	46.00	177.30	156.50	15.90	127.10
2010	37.50	58.80	203.90	217.00	313.70	139.80	80.50	147.50	126.60	238.70	24.30	25.20
2011	11.00	314.90	39.50	135.60	276.40	110.50	99.20	180.30	190.00	223.60	198.70	11.50
2012	14.80	34.10	29.20	136.40	198.90	113.70	168.98	136.70	175.90	181.20	54.10	88.28
2013	16.90	12.40	207.90	175.50	231.50	98.30	153.20	229.90	215.40	216.96	112.20	25.38
2014	8.80	23.60	122.60	134.50	368.50	74.90	96.70	104.90	140.40	218.30	109.60	12.60
2015	6.30	21.80	72.10	145.30	162.90	159.00	81.20	60.70	140.00	151.70	95.50	52.00
2016	31.50	31.90	56.00	201.20	233.30	135.67	83.51	155.60	66.90	175.60	75.10	22.80

Table a 3 : Average monthly rainfall (mm) of the Kebado Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	61.90	0.00	25.30	318.10	273.80	127.60	152.40	102.70	162.80	236.60	156.90	68.90
1998	73.40	94.70	98.50	171.43	137.00	120.80	124.20	99.40	185.30	192.60	90.00	15.90
1999	18.80	25.90	187.00	88.00	312.50	99.30	76.20	99.80	141.40	211.90	28.20	26.10
2000	4.40	37.40	20.80	139.10	175.70	39.30	116.70	151.30	189.80	211.10	82.00	30.40
2001	18.70	32.80	105.10	183.00	169.50	193.00	81.40	172.70	215.20	292.50	70.60	40.10
2002	35.90	6.60	188.80	55.30	182.60	139.50	30.80	91.60	175.80	135.10	14.60	95.40
2003	43.90	3.80	54.80	226.80	163.80	144.80	56.10	134.70	120.20	122.00	59.30	32.80
2004	36.30	63.10	58.90	171.40	153.00	34.00	58.10	106.60	147.10	73.30	89.80	85.40
2005	17.70	7.20	120.10	287.10	209.50	145.90	76.60	59.20	177.50	156.30	17.90	0.00
2006	21.00	55.60	127.50	195.50	207.50	115.20	121.80	160.10	150.20	358.70	77.10	13.60
2007	50.40	75.20	90.30	158.50	271.10	106.50	68.20	280.70	293.10	184.10	36.70	42.60
2008	2.60	10.40	42.10	168.00	285.10	83.30	90.80	62.00	282.50	197.60	66.70	7.90
2009	84.80	28.00	102.00	176.10	192.70	49.00	26.40	54.40	211.80	168.10	6.00	96.90
2010	47.30	130.70	162.90	289.60	282.00	165.60	147.50	181.70	95.40	119.10	26.70	5.60
2011	12.20	15.40	27.90	116.50	272.00	71.20	39.80	252.80	262.10	135.30	127.40	9.70
2012	4.60	0.00	48.10	166.00	128.10	184.60	92.90	275.10	121.00	41.90	31.90	28.70
2013	7.30	107.30	209.70	119.70	101.20	54.00	139.70	150.40	67.80	68.20	75.20	39.00
2014	7.20	27.50	159.60	168.80	305.50	157.40	182.00	123.00	204.80	38.60	51.00	36.00
2015	0.00	21.00	89.60	156.70	123.50	74.80	47.60	51.10	102.20	145.80	68.20	31.50
2016	0.00	25.70	95.40	143.20	80.40	122.00	60.60	131.50	113.90	135.00	64.30	61.00

Table a 4: Average monthly rainfall (mm) of the Bule stations

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	11.60	27.90	0.00	122.33	168.10	106.60	63.90	201.10	277.30	285.00	40.40	11.90
1998	40.60	139.10	80.50	195.40	213.40	172.50	123.50	148.00	117.70	221.40	69.60	54.80
1999	9.60	25.30	60.60	267.40	139.80	201.00	59.70	165.40	128.70	130.50	54.60	68.20
2000	47.40	53.90	51.70	258.80	279.70	148.60	84.00	137.20	256.70	231.40	83.30	44.20
2001	48.80	15.50	47.20	272.50	195.30	217.70	179.30	258.00	226.00	179.60	85.50	42.00
2002	4.80	10.90	58.20	104.60	183.60	176.40	102.80	186.30	111.00	131.30	107.90	52.30
2003	48.70	11.30	78.60	163.90	112.00	189.30	145.30	143.50	140.60	72.10	71.50	39.10
2004	40.10	44.50	26.20	284.40	132.60	214.10	220.10	260.90	206.10	117.40	95.10	68.00
2005	26.60	15.50	55.00	156.20	342.40	152.20	49.20	134.30	276.60	293.60	48.80	0.00
2006	13.00	45.60	114.00	275.90	185.50	135.40	82.70	153.50	75.10	101.30	43.80	64.40
2007	37.20	31.30	49.70	186.90	167.70	238.10	100.50	159.90	171.30	149.50	124.90	19.30
2008	4.80	10.90	58.20	104.60	183.60	176.40	102.80	186.30	111.00	131.30	57.60	52.30
2009	34.80	66.30	90.40	223.80	154.00	102.00	42.10	133.20	178.30	146.50	82.50	56.90
2010	26.20	57.30	213.10	205.10	336.80	106.20	155.00	179.80	240.60	189.70	12.00	14.60
2011	33.00	38.00	33.60	118.00	271.10	74.30	195.00	181.40	207.20	114.90	145.50	37.80
2012	5.50	3.00	0.00	161.40	180.50	231.10	129.30	103.80	154.80	201.80	125.60	48.20
2013	0.00	46.10	161.00	223.70	264.60	81.90	168.70	197.10	232.50	200.80	91.10	0.00
2014	23.70	54.30	94.30	97.40	163.20	152.00	67.60	134.60	119.60	83.50	61.80	34.20
2015	8.20	55.60	133.16	213.90	112.70	164.00	45.70	96.60	136.30	186.30	74.20	65.70
2016	18.60	63.10	55.90	167.10	152.00	108.10	33.40	108.30	32.40	188.20	87.20	24.80

Table a 5: Maximum and Minimum Temperature of the Dilla station

	°C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	Max	30.86	32.88	33.32	28.17	27.27	27.41	25.97	26.96	27.63	26.94	27.00	27.73
	Min	9.95	10.45	12.88	13.81	12.42	13.16	14.17	13.92	12.75	14.75	14.37	12.86
1998	Max	27.90	29.85	30.80	30.27	28.32	27.58	26.85	25.78	25.11	25.97	28.28	29.89
	Min	13.91	14.02	13.61	12.98	14.09	13.35	15.36	15.41	14.26	14.53	10.15	7.10
1999	Max	30.70	32.99	28.39	28.95	26.65	26.74	25.37	26.83	26.19	25.94	28.89	30.05
	Min	8.35	8.12	12.41	12.28	13.08	13.03	13.37	13.30	12.84	12.49	11.13	9.67
2000	Max	31.64	32.96	33.81	24.14	23.12	22.30	21.70	21.83	22.21	22.47	23.07	23.68
	Min	9.91	10.45	11.90	12.98	13.08	13.07	13.36	13.26	12.88	12.45	11.06	9.64
2001	Max	24.84	25.19	26.73	24.14	23.12	22.30	21.70	21.83	22.21	22.47	23.07	23.68
	Min	9.95	10.45	11.90	12.98	13.55	13.69	14.36	14.53	13.35	13.85	11.37	10.46
2002	Max	24.84	25.19	30.33	29.50	27.85	26.97	26.49	27.25	27.61	29.99	28.83	29.73
	Min	10.67	9.50	13.75	13.49	14.03	14.00	13.49	14.03	13.55	12.98	12.29	13.42
2003	Max	30.23	33.86	33.66	29.78	28.85	22.47	21.74	21.80	22.20	22.44	23.05	28.18
	Min	10.75	9.66	10.73	13.63	13.17	13.08	13.37	13.30	12.84	12.49	11.13	9.45
2004	Max	27.60	29.75	31.18	27.00	28.04	26.10	26.17	26.79	26.70	27.40	28.20	29.25
	Min	11.16	11.36	11.33	14.44	12.86	13.05	13.58	14.46	13.26	12.33	12.72	11.63
2005	Max	30.75	32.79	31.15	30.13	25.98	26.17	25.49	26.50	26.46	26.46	27.99	29.89
	Min	10.12	10.47	13.82	14.06	14.94	13.80	13.74	14.32	13.99	13.64	11.40	7.20
2006	Max	31.19	30.75	29.61	27.42	27.60	27.26	25.40	25.99	26.66	27.19	27.50	28.06
	Min	9.85	12.31	13.32	14.12	13.58	13.91	14.87	14.09	13.98	14.76	13.15	12.66
2007	Max	29.46	31.04	29.39	28.34	28.39	27.05	26.16	25.75	25.69	27.09	27.22	29.03
	Min	12.27	12.32	11.70	13.92	14.25	15.24	14.75	14.44	14.82	12.09	11.88	8.15
2008	Max	30.65	30.93	31.72	28.46	26.09	25.88	24.64	25.20	26.30	26.31	27.29	29.20
	Min	9.15	9.98	11.07	13.73	14.06	13.92	15.15	14.43	14.37	13.80	11.48	9.21
2009	Max	29.64	30.94	32.34	28.13	27.78	27.27	26.88	27.59	27.18	27.38	29.46	28.17
	Min	10.20	11.24	12.44	14.34	13.08	13.19	13.57	13.78	14.20	14.06	11.35	17.47
2010	Max	29.20	29.45	28.46	27.95	26.84	26.44	25.06	25.59	25.91	27.49	29.45	29.93
	Min	11.32	14.81	14.45	15.03	15.70	14.74	15.07	15.39	14.72	13.94	11.09	9.60
2011	Max	31.04	9.73	30.96	31.89	27.08	26.01	25.87	25.53	25.49	27.29	26.58	27.87
	Min	10.03	9.73	12.55	13.69	15.42	15.19	14.75	14.87	14.55	13.03	13.79	10.15
2012	Max	30.67	31.82	32.38	28.28	27.50	24.79	21.70	26.01	25.43	27.30	28.01	29.15
	Min	8.15	8.06	10.80	14.17	13.87	14.55	13.36	14.73	14.35	13.25	11.06	11.10
2013	Max	30.58	32.30	30.14	27.55	26.35	23.96	24.72	24.99	26.23	26.09	27.19	28.58
	Min	10.43	10.61	15.36	14.85	13.08	14.94	15.11	14.56	14.10	14.03	12.91	9.64
2014	Max	30.17	30.28	30.66	28.57	27.01	26.69	25.96	25.84	26.18	26.31	27.65	28.56
	Min	10.55	12.92	12.98	13.13	14.30	13.57	14.45	13.90	13.56	14.19	12.61	9.93
2015	Max	30.38	31.92	31.05	28.78	27.59	26.66	26.69	27.94	27.53	27.64	27.94	28.41
	Min	8.05	9.93	11.78	13.56	14.35	14.39	14.06	13.05	13.02	13.72	11.18	9.67
2016	Max	30.56	31.83	31.76	28.40	27.20	26.23	25.12	21.83	26.51	26.99	28.24	29.12
	Min	13.19	11.68	13.55	16.13	15.02	13.97	15.48	13.26	13.76	14.09	12.12	9.32

Table a 6: Input files for the weather generator in SWAT model

Variables	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TMPMX	29.65	29.82	30.89	28.29	26.93	25.81	24.98	25.39	25.77	26.36	27.25	28.41
TMPMN	10.40	10.90	12.62	13.87	13.90	13.89	14.27	14.15	13.76	13.52	11.91	10.42
TMPSTDMX	1.93	5.25	1.81	1.81	1.50	1.72	1.80	1.99	1.69	1.89	1.96	1.77
TMPSTDMN	1.50	1.74	1.25	0.86	0.89	0.74	0.75	0.69	0.67	0.83	1.06	2.35
PCPMM	39.81	67.53	184.48	152.42	189.9	126.82	112.97	148.94	138.03	180.94	72.22	38.01
PCPSTD	3.45	5.33	9.08	7.87	9.13	6.70	5.58	7.83	7.26	8.70	4.95	2.95
PCPSKW	4.50	4.09	2.18	2.86	2.78	2.96	3.07	3.13	3.24	2.27	3.36	5.53
PR_W1	0.16	0.29	0.34	0.46	0.47	0.41	0.41	0.45	0.39	0.25	0.26	0.14
PR_W2	0.51	0.55	0.75	0.70	0.78	0.69	0.71	0.72	0.98	0.81	0.65	0.69
PCPD	8.30	11.65	18.60	18.90	21.9	18.00	18.95	19.70	19.30	18.90	13.45	10.50
RAINHHMX	26.54	45.02	122.99	101.61	126.6	84.55	75.31	99.29	92.02	120.63	48.15	25.34
SOLRAV	8.52	8.33	7.92	6.95	6.30	6.01	5.05	5.56	5.85	6.64	7.82	7.98
DEWPT	8.08	8.24	13.3	11.4	11.24	11.54	11.39	11.77	11.78	12.23	9.94	9.51
WNDAV	0.44	0.73	0.54	0.40	0.30	0.27	0.27	0.27	0.27	0.28	0.27	0.30