A Decision Support System for Integrated Water Resources Planning and Management in the Nile Basin

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The Nile River Basin covers about 10% of the African continent and is spread over ten countries (Burundi, Congo, Egypt, Eritrea, Ethiopia, Kenya, Sudan, Tanzania, Uganda, and Rwanda). Almost all Nile water is generated on an area covering 20 percent of the basin (most notably the Ethiopian and the Equatorial Lake Plateaus), while the remainder is in arid or semi-arid regions. Egypt and Sudan are almost totally dependent on the Nile for their water uses. And, most other Nile countries are close to water stress, if not already below the water scarcity threshold of 1000 m^3 of water per inhabitant per year. Water stress is compounded by rapid population growth, occurring at twice the global average rate. Hence severe water scarcity conditions are looming over most Nile countries. Nile Basin economies are heavily depended on agriculture which accounts for more than half of the Gross Domestic Product and employs more than 80% of the workforce. However, the lack of water infrastructure, marked climate variability, and poor cultivation practices have seriously restrained, if not completely halted, economic growth.

Under the aegis of United Nations Agencies, International Aid Agencies, and the World Bank, the Georgia Water Resources Institute developed a state-of-the-science decision support system to support the information and decision making needs of the Nile Basin nations. The purpose of the GWRI decision support system (Nile DSS) is to evaluate the merits of various water development and management strategies and support the integrated and efficient utilization of the regional water, energy, and environmental resources.

The Nile Decision Support System (Nile DSS) includes planning and operational components used by individual countries as well as basin planners. These include satellite-based remote sensing; climate and hydrologic forecasting; river basin simulation, management, and scenario assessment; agricultural planning; and hydro-thermal power system planning. This presentation will provide an overview of the Nile DSS methods and applications including assessing the basin-wide tradeoffs between hydropower and agricultural developments, and the potential impacts of climate change.

Evaluation of the spatial variability of Impact of Climate Change on Water Resources Availability of Blue Nile Basin: a case study of ten catchments in the Upper Blue Nile in Ethiopian

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The purpose of this study was to understand the spatial variability of climate change impacts within the Blue Nile basin on the basis of hypothetical climate change scenario and using HBV hydrological model. The assessment was done on ten selected catchments of the basin. A hypothetical scenario with upward and downward incremental increase of up to 30 % has been considered in the input series of precipitation and Potential ET time series.

The HBV conceptual hydrological model was initially calibrated and validated with the original data sets before being perturbed to the input series of the ten catchments investigated. The performance of the model was evaluated using the Nash and Sutcliffe efficiency criteria. The calibration efficiency varies in the range of 0.61 and 0.83 and while the verification efficiency is slightly less and varies between 0.56 and 0.79.

The impact assessment has shown that Chacha (slope = 3.02) located in the eastern part of the basin is the most sensitive catchment followed by catchments Sechi (slope = 2.35). Guder, Teme, Muger, Birr. Koga, Neshi, and Little Anger are less sensitivity catchments from the Blue Nile basin. Spatially, the area in the south west and south eastern part of upper Blue Nile are the most sensitive part of the basin for climate change. The study doesn't show absolute climate change impacts in the basin rather it provides relative sensitivity of catchments to climate change within the basin for further consideration for policy actions and prioritizing adaptation and mitigation measures in the event of the effects of climate change in the water resources of the basin.

Simulation of future water resource development in the Blue Nile

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The riparian countries of the Nile have agreed to collaborate in the development of its water resources for sustainable socio-economic growth. Currently there is significant potential for expansion of hydropower and irrigation in the Blue Nile River in both Ethiopia and Sudan. However, the likely consequences of upstream development on downstream flows have not been fully assessed and the water resource implications of development in both countries are unclear. Against this background, the Water Evaluation And Planning (WEAP) model was used to provide a preliminary assessment of both the current situation and plausible future development scenarios. Two scenarios were created; one simulating likely development in approximately 2015 and the other simulating possible development in approximately 2025. Data for all existing and planned schemes were obtained from the basin master plans as well as scheme feasibility studies. In each scenario, new irrigation and hydropower schemes on both the main stem of the Nile and its principal tributaries were included. Water use was simulated over a 32-year period of varying rainfall and flow. Shortfalls in water supply to schemes were analyzed and levels of assured supply determined. The study illustrates the value of scenarios to provide insight for resource planning and to evaluate the implications of different options for meeting future water demand.

The Value of a Precipitation Forecast on Hydropower Production in Ethiopia

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The upper Blue Nile basin in Ethiopia harbors considerable untapped potential for large-scale hydropower development. Current management of existing hydropower systems within the country relies on month-to-month monitoring and persistence (climatology) for reservoir operations. This research investigates the value of incorporating a seasonal precipitation forecast as part of a coupled system for guidance in hydropower decision-making. Two large-scale dams, Karadobi and Border, proposed for hydropower development along the main stem of the Blue Nile, serve as application sites. To assess the forecast value, an ensemble precipitation forecast model is linked to a physically-based hydrology model, and subsequently a hydropower model and compared to a similar system in which no forecast is issued, relying on climatology. Ensuing benefits from hydropower generation are compared. The systems are independently subjected to historical climate conditions and wet and dry climate trends, representing climate change. Under historical climate conditions, for the 40-year study period, the forecast based system outperforms the non-forecast based system by more than 100 million US dollars. Preliminary results indicate similar findings under climate change conditions.

Trends in Runoff and Rainfall in the Blue Nile Basin: 1964-2003

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Potential future water shortage in the downstream countries in the Nile basin is of great concern worldwide. Most Nile water originates in Ethiopia but there is no agreement on how land degradation and climate change affect the flow. The objective of this paper to improve understanding of future conditions by analyzing historical trends and its causes. The data rich Upper Blue Nile River Basin for the period 1963 to 2003 was selected. Both the seasonal Mann-Kendall and Sen's T test were used the trends analysis and the Trend Free Pre-Whitening (TFPW) approach for autocorrelation correcting. A rainfall runoff model examined the causes for observed trends. The results indicate that no significant trends in the seasonal and annual rainfall existed. Discharge in the long rainy season (June to September) the short rainy season (March to May) increased significantly at the three key stations. As a percentage of the 40-year mean, these increments are for the long rainy season were 26% at Bahir Dar, 27% at Kessie and 10% at El Diem. For the short rainy season discharge increased 33% at Bahir Dar, 51% at Kessie but less 4% at El Diem. During the dry season (October to February) no significant trends at Bahir Dar and Kessie was observed but a significant decreasing trend at El Diem by 10% of the 40 years seasonal mean. The rainfall runoff model reproduced the observed trends, assuming that 15 % of the hillsides were eroded in a 30 year time span and generated overland flow instead of interflow.

Climate change scenarios for Ethiopia

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Impacts of Climate Change and Variability to Water Resources Management

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Kenya is highly vulnerable to rainfall variability and climate change. Extreme weather events including droughts and floods are becoming more frequent. The country's resilience to droughts is highly compromised by the fact that over 80% of the total surface area is arid and semi-arid land (ASAL). Furthermore, catchment degradation, with impacts on water quality and quantity, and water resources pollution is also impacting negatively on available water resources, and places additional financial and social burden on the population of Kenya compared to other countries that have abundant water resources. Climate change will have direct impacts on water resources and agricultural production among other sectors. Most climate prediction models "the General Circulation Models" predict an increased frequency in extreme climate and severe weather events particularly in the tropical region. This will therefore result into short duration storms with intense frequencies leading to severe events of floods and droughts.

Climate change is challenging the task of providing sufficient water by exacerbating the element of uncertainty and surprise, with increased frequency of water-related disasters. Climate change projections to the year 2030 for Kenya indicate increasing temperatures with doubling of CO_2 levels from baseline scenarios resulting in a decline in rainfall (between 5 and 15 percent) in the semi-arid areas and an increase of 5 to 45 percent in rainfall in the wetter areas (GoK, 2002). The expected scenarios in semi arid areas will include increased aridity and flash floods and incidence of diseases, food insecurity, and shortage of forage and breakdown of infrastructure. The likely scenarios in the wetter areas include flooding, land slides, erosion, and siltation of reservoirs, water-related diseases, food insecurity and destruction of infrastructure. The increasing levels of water catchment degradation and scarce water resources are a worrying trend in Kenya.

Kenya is classified as a water scarce country. Her fresh water endowment at 647 meter cubed per capita is below the global bench mark of 1,000 meter cubic per capita. This situation is expected to deteriorate further such that the projected water per capita in 2025 is expected to be 235 meter cubed. Even with the best mitigation strategies, some impacts of climate change are now all but certain. The challenge for many nations is, thus, learning how to adapt. Climate adaptation is to a large extent about water, or more specifically, water management. Water management has always been about planning for variability. Changes in water demand, droughts, floods and economic cycles have always been part of effective water planning and infrastructure development. Water is the medium through which climate change manifests its most serious effects, so it is the logical frontline for adaptation strategies.

Nations need to formulate a climate policy that integrates water management as a cross-sectoral tool for adaptation. This will make water needs to feature out prominently in climate change discussions and negotiations. The policy formulation will aid in achieving some of the Millennium Development Goals for health, hunger, energy, sanitation, and social progress.

Evaluation of Climate Change Impact on Upper Blue Nile Basin Reservoir

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Nowadays the sign of climate change and its impact is revealing on different natural and man made systems, in one or other ways. However, this impact is significant on the water resource system. This study mainly deals with evaluation of the climate change impact on the Gilgel Abay reservoir using the reliability, resilience and vulnerability indices (RRV-criteria). Projection of the future climate variables is done by using General Circulation Model (GCM) which is considered as the most advanced tool for estimating the future climatic condition. Statistical Down Scaling Method (SDSM) is applied in order to downscale the climate variables at catchment level. The simulation of reservoir and its future inflow is carried out by using HBV-hydrological model with calibrated (R2=0.82) and validated (R2=0.8) values. The projected future climate variable shows an increasing trend for both maximum and minimum temperature however, for the case precipitation it doesn?t manifest a systematic increase or decreasing trend in the next century. The evaporation from the open water surface of reservoir reveals an average annual increase by 2.1 % when the projected average annual temperature and precipitation increases from the baseline period by an amount of 0.53oC and 0.82 % respectively in 2020s, under A2a emission scenario. When the average annual temperature is rise by 1.15 oC and the precipitation increase by 0.85 % in 2050s with A2a emission scenario, the reservoir open water evaporation will expected to increase by 6 %, while in the time horizon of 2080s, the precipitation shows an increase amount by 1.6 % and the temperature raise 1.97 oC consequently the open water evaporation is expected to rise by 22 % for the same A2a emission scenario.

On average for both A2a and B2a emission scenarios the time based reliability (the probability of the reservoir to meet the target demand) of Gilgel Abay reservoir shows a value of above 80 %, i.e. 80% of the time the target demand is fully supplied and the resilience (the speed of recovery of the reservoir, form failure) shows value above 60%, a value of 100% resilience shows the reservoir needs very short time to recover itself from failing to meet the demand and the dimensionless vulnerability (the average volumetric severity of failure during failure period divides by the target demand) of the Gilgel Abay reservoir falls in range (25%-30%).The sensitivity analysis of the reservoir with a hypothetical climate change scenario indicates that the reliability and resilience of the reservoir is sensitive to precipitation change than change in temperature on contrary dimensionless vulnerability of the reservoir doesn?t show remarkable difference for both the change in precipitation and temperature.

Impacts of Land Use and Climate Change on Water Resources, Hare Watershed, South

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Knowledge how land use and climate change influences watershed hydrology enables to formulate and implement effective and appropriate response strategies to minimize the undesirable effects of future changes. Land use change scenarios will enable to identify and analyze possible land management options that can be incorporated in watershed management planning. On the other hand, analysis made on climate change will help to predict possible climate change scenarios that might occur in the coming decades. An integrated approach of these impacts on water resources thus will assist policy makers, researchers and farmers to prepare appropriate measures ahead of time. This study investigates the impacts of land use and climate changes on hydrological regimes and consequent impacts on downstream irrigation water users at Hare River Watershed.

Appropriate three land use change scenarios were developed based on past and present land use/cover change analysis. SWAT2005/ArcSWAT, a physical-based semi-distributed watershed model with ArcGIS interface, was utilized to predict the impacts of these changes. Conversely, a Global Climate Model (HadCM3) was used to develop climate change scenarios and a Statistical Downscaling Method was adopted to reduce regional climate change to watershed level. Use of the ArcSWAT modelling environment enabled to partition the watershed into sub-watersheds, and consequently to Hydrologic Response Units that consist of homogeneous land use, slope and soil characteristics. Prior to future land use and climate change impact analysis, the model was calibrated and validated with the existing data to reduce uncertainty and provide parameter estimation guidance. Ultimately, simulation that take in to account climate change scenarios were made to acquire valuable information on the upstream-downstream linkages with respect to land use management interventions in the upland areas and resulting impact at the downstream water users.

Results from the HadCM3 for the coming hundred years showed that an increase in future average annual precipitation by 10-22% and average temperature by 2.1oc when compared to the baseline period. Model calibration and validation results on daily and monthly bases pointed out that ArcSWAT performs quite satisfactory. The outputs from the three land use change scenarios were compared to the baseline run. All three scenarios gave an increase in discharge during wet months (4.5 to 12.5 %), and a decrease during dry periods (-4.5 to -7.9 %). Furthermore, the results indicated that small scale irrigation intervention in the upper part of the watershed without other conservation and management activities can reduce water availability at the downstream reach of the watershed

Linking Seasonal Climate Variability Information to Maize Productivity in Gojjam

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As a country whose economy is heavily dependent on rainfed agriculture, rainfall variability are often cited as one of the most important factors in explaining various socio-economic problems such as food insecurity. Therefore, in order to help policymakers and developers make more informed decisions; this study investigated the temporal dynamics of rainfall and its spatial distribution within Gojjam, Amhara regional state of Ethiopia. The degree of yield variability over time is changed not only by the amount of rainfall, but also by its patterns like onset date, end date, dry spell and rainfall duration, which in case of agriculture pose critical risks to the farming community . Using station level rainfall data from 1953-2005 and agricultural production data of maize crop from 1995-2005 for Gojjam, this study attempts to show patterns of rainfall and provide insight into the preparation of an early warning system for yield by dividing the study area into homogenous rainfall zones using cluster and EOF/PCA methods. ENSO phases are also correlated with drought years in maize production.
Climate and yield data as well as, different oceanic indices were obtained from National Meteorological Agency of Ethiopia, Central Statistics Agency of Ethiopia and the website of NOAA/Climate Prediction Center respectively. Spatial and temporal rainfall variability was assessed in terms of some agriculturally important patterns like the time of onset date, end date and rainfall duration. Accordingly, the time of rainfall onset date and rainfall duration are useful for making the decisions related to when and which cultivar to plant more significant. Integrated result of hierarchical cluster analysis and PCA technique divides the area into two homogenous zones. The stepwise multiple linear regression method was used to develop the maize yield forecasting model and developed models for each cluster group representative (Bahir Dar and Debre Markos) are powerful to predict maize yield of the study area and most predictors are from Atlantic Ocean indices. The assessment on whether ENSO phases have effect on seasonal rainfall amount and crop yield using composite analysis showed that El Niño decreases the JJAS season rainfall and crop productivity. It is also characterized by late rainfall onset, early end date and shorter growing period. La Niña increases JJAS season rainfall and crop productivity. Above all, by improving data managing system extend the study to the whole country through classification of the area into homogeneous zone, assessing sub seasonal climate variability, developing rainfall predicting model, checking dry spell and crop water requirement, assessing cause of climate variability with respect to oceanic and atmospheric systems, relate rainfall with global oceans of SST and pressure anomalies that are in turn important for seasonal rainfall prediction should be future works.

Climate Change, Climate Variability, Impacts in the Water Sector

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Today climate change is a burning issue all over the world because of its global nature. Fears have arisen that; climate may be changing for the worse and its impact on agricultural production, which will reduce the supply of food to growing population, especially in developing countries. Climate change would affect various human activities. Agriculture is one of the activities, which can e seriously affected by climate change. Due to high inter-annual variability and uneven distribution of rainfall during the rainy season, recurrent droughts have observed in semi-arid tropics of the world over the last three decades. As White, (cited in Climate Variability and Agriculture by Y.P Abrol, S. Gadgil and G. B.Pant 1996) pointed out rain fed agriculture in the semi-arid tropics is limited mostly by high climatic variability with principal limiting factor being rainfall. The main crops of traditional rain fed agriculture are sorghum, millet, maize, cowpea, pulses, and sesame. Adverse climatic conditions are the bottleneck of Ethiopia?s rain fed agriculture development. Besides, agricultural production suffers from periodic outbreak of pests and diseases, both pre- and post harvests, in most parts of Ethiopia. Some pests are becoming a serious problem in some areas where the rainfall condition is erratic. For instance, Sorghum Chafer becomes a chronic problem since 1993 over northeastern highlands of Ethiopia including Afar regions.

The objective of the research study is to identify and characterize the effect of climate change on agriculture by assessing the climatic condition of the selected areas and its effect on agriculture.

Lake Haramaya Watershed Delineation and its Groundwater Recharge Estimation Using Chloride Mass Balance Method

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Due to rapid population growth in Haramaya Watershed, Harar and its surroundings, the exploitation of groundwater resources has increased substantially upon drilling new wells in the last five- ten years. Over-pumping of the groundwater is feared to have overarching adverse consequences. Hence the knowledge of the safe and sustainable yield is imperative. This research was therefore, prepared and executed with two specific objectives of watershed delineation and groundwater recharge estimation using Chloride Mass Balance (CMB). In the present study, for the first time, the CMB method was adopted to estimate groundwater recharge in the watershed. Haramaya watershed was delineated using the aerial photos of 1996, topographic maps of 1999, DEM, contour map generated from SRTM data, 3D visualization and intensive field survey using GPS. Land use/ land cover map of the watershed was produced. Water samples for chloride analysis from five bore wells of the University, four bore wells of Harar town, and four hand dug wells of the local communities were taken at four different times with a total of 52 water samples. Eight rainfall collectors with three consecutive days for each four trip at different times with a total of 96 samples were collected at different elevations to represent the whole watershed to facilitate the estimations using chloride mass balance method. The average rainfall chloride concentration obtained from a total of 96 samples was 17.11 mg/l and the average groundwater chloride concentration from 52 samples was 106.91 mg/l. Based on the measured and calculated results, in all sites, average recharge to the groundwater was calculated to be 121.95 mm/a which is 16.00% of the annual rainfall (762 mm). This shows that the total amount of water recharging was estimated to be in the order of 6,381,213 m^3. The average annual rainfall falling in the catchment (52 km^2) is estimated to be 39,624,000 m^3. Currently, the amount of estimated water abstractions by the Harar town, University and local community were 1,434,968 m^3, 597,607 m^3 and 827,056 m^3 respectively with a total abstraction of 28 Though these findings need to be triangulated with the findings of other alternative methods currently in progress, the indications are that ground water is safe as it stands. However, the researcher has made his level best to be based on factual evidences, one had to be very cautious in the findings of this research until it is cross-checked with alternative methods of recharge estimation.

Water Resources Potential Assessment of Simada Wered A with Particular Reference to Ground Water. A Case Study of Bijena-Muye River Catchments, South Gondar, Ethiopia

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The main objective of this research is to assess the available water resources potential of Simada Wereda for sustainable development. In this paper the annual groundwater recharge, surface runoff, groundwater returns as base flow, spatial variability of hydrochemistry, groundwater potential zones and annual water budget of the area were identified. Rainfall was generated using Theissen polygon method using available data from meteorological stations, and stream flow data was generated by down scaling the Ribb river flow data using area ratio method. The hydrochemistry of the study area was identified using field and laboratory analysis methods. In the laboratory major cations and anions were identified. In terms of water quality all waters analyzed are in the standards of World Health Organization (WHO) and Ethiopian Standard Authority.

In this work the annual rainfall, actual evapotranspiration, potential evapotranspiration, recharge (soil moisture surplus) and the change in groundwater flow were 1053.0mm, 667.0mm, 935mm, 212mm and 7mm respectively. The hydrochemistry study shows that there is spatial variation in the chemical and physical properties? of water. TDS, temperature, and EC increase from highland areas to low land areas. Based on the analytical results, all water types are HCO3 except the thermal spring which is HCO3-Cl type and Ca-Ma and Na are the major cations. From groundwater point of view four general potential zones are delineated by combining t lithology, geomorphology, and soil maps of area. These zones are categorized as high, moderately, slightly and least potential zones.

As a whole this paper is very important to be used in water resources development work in future as it contains the basic water budget components.

Universal Kriging of Water Levels in the Addis Ababa/Akaki Aquifer

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Accura Engineering Cons

Universal kriging is applied for spatial analysis of groundwater levels in the Addis Ababa Ababa/Akaki Aquifer. Groundwater level data of 134 wells, which were collected in 1999 by Addis Ababa Water Supply and Sewerage Authority, were used in the study. Directional experimental variograms that characterizes the spatial variability of the water level data in different directions were constructed, and authorized theoretical variogram models were fitted to the experimental variograms by generalized least square method. Analysis of the variograms showed that the water level data are stationary in West-East direction, and are non-stationary in the North-south direction indicating the need for universal kriging. The variogram in the West-East direction (least drift) was considered as the underlying variogram, and the drift order was determined from the cross-validation procedure. The latter was also used to asses the validity of the chosen variogram model. The cross-validated variogram model was then used to estimate the groundwater levels and the corresponding estimation variances at the nodes of a square grid of 1 km x 1 km, and to develop kriged groundwater level contour map.

How to close the water balance of Lake Tana?

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In our several published studies, closure of Lake Tana water balance is obtained by runoff from ungauged catchments. The first two studies applied simple *ad-hoc* procedures on area comparison to estimate runoff from ungauged catchments. This study extends on the study by Wale et al. (2009) with emphasis is on more advanced approaches as based on regionalisation and spatial proximity principles. In this work the HVB-96 model is selected while automated calibration is by a Monte Carlo procedure.

Closure of the lake water balance was established by comparison of measured to calculated lake levels. A recent bathymetric survey is used to establish volume-area and volume-level relations. Daily lake level simulation shows a relative volume error of 2.17% and a Nash-Sutcliffe coefficient of 0.92. Results show that runoff from ungauged catchment is around 527mm per year for the simulation period 1994 to 2003 while the closure term only is some 85mm.

Integrated Water Resource Assessment of South Wollo Region, Beshilo Catchment

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This study was intended to adopt a better understanding of the Hydrological and Hydrogeological system of a basin and assess the water resources using integrated techniques as well as, put an emerging technical capabilities to perform broad-scale, national, and integrated, multi-factor water resources assessments from the quantitative estimation of the available surface & ground water resource of spatially distributed aquifers that characterized ground water recharge, discharge and storage, at small scale basin using SWAT model.

The landuse/landcover, soil and slope options of SWAT model defines the landuse/landcover and soil properly, which then are used to define the hydrological response units (HRU) distribution in each sub -basin. The interactions between surface and subsurface flow in SWAT are based on a linked surface-subsurface flow model developed by Arnold et al. (1993).

The most important parameters contributing to an integrated water resource assessment are rainfall, evapotranspiration rate, and surfacial lithologic cover. The area has an annual rainfall of 1087mm, quantification of potential and actual evapotranspiration of the area is made using SWAT model and cross checked by different empirical techniques.

Since the catchment is un - gauged catchment, the discharge measurement at the outlet is interpolated from the homogeneously rationalized neighbouring station, using a aerial ratio method

Water balance studies of the catchment indicate that, surface runoff 277.3mm and 213mm of water is recharged to shallow and deep aquifer annually, the moisture deficit at months January, February, May and December, where as July and August are months of moisture replenishment, lately moisture surplus is held for two consecutive months in August and September.

The main aquifer identified in the catchment that covers 46% of the total area are the alluvial sediment and highly weathered, fractured and tilted basalt of the oldest trap of volcanic series is known as the Ashangae basalt.

Regimes of Borkena Catchment for Irrigation Development Using Rainfall-Runoff Modeling

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Kombolcha TVET Col

The main objective of the research is to reconstruct flow regimes of Borkena catchment in ungauged locations for irrigation development using rainfall-runoff modeling. Four black-box-type rainfall-runoff models, namely, Simple Linear Model, seasonally based Linear Perturbation Model, wetness-index-based Linearly Varying Gain Factor Model, and Artificial Neural Network Model, along with the conceptual Soil Moisture Accounting and Routing Model, were used to test the hydrological response of the Borkena catchment.

The performance of these hydrological models for the study area was tested and the best candidate model for the catchment response prediction was selected. Artificial neural network model was selected as a robust rainfall-runoff model to obtain the estimated flow of the gauged station which is the basis to transfer flow data to ungauged sites on the catchment.The R2(R square) during calibration and verification was 97.57% and 91.30% respectively.

On the basis of the selected model 15 days 75% dependable flow derived from the flow duration was used as the basis of estimating dependable low flows at ungauged locations of the catchment using area ratio method of transferring flows.

Spatial Runoff and Mapping of Potential Water Harvesting Areas: A GIS and Remote Sensing Perspective

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Freshwater resources scarcity is becoming a limiting factor for development and sustenance in most parts of Ethiopia. The Debre Mewi watershed, in northwestern Ethiopia is one of such areas where the need for supplemental water supply through rainwater harvesting is essential. Suitable water harvesting sites were identified through overlay analysis considering both social and technical parameters, such as land use/land cover, slope gradient, soil texture, flow accumulation and stakeholders' priority with the integration of GIS and Remote Sensing applications. Knowledge of runoff due to rainfall is most important for designing any water harvesting structures. Direct measurement of runoff is always good but time consuming, labor intensive and expensive. In conditions where direct measurement of runoff could not be possible, remote sensing technology and GIS combined with runoff models are proven to be effective. In this study, the remotely sensed satellite data (Quickbird2) provided spatial information on land use/land cover. Precipitation and soil data were obtained from the nearest meteorological station and laboratory analysis results, respectively. The GIS tools were used to store, manipulate and estimate runoff depth, surface storage and runoff volume applying Soil Conservation Service (SCS) Curve Number (CN) formula. The direct runoff volume estimated using SCS-CN model is 146,697m^3 for the month of August, at Debre Mewi watershed, which covers about 508ha. The result is compared with measured values and closer relationship was found. Remote sensing was found to be a very important tool in providing input parameters. GIS was also found to be a very important tool in mapping and integrating the different variables, in the process of runoff estimation and suitable water harvesting sites selection.

Advancing hydro-meteorological monitoring and forecasting through network of low-cost mini-radars

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We seek to develop a state-of-the-art hydro-meteorological observational-modeling system, based on network of advanced low-cost mini X-band polarimetric radars. The system will greatly enhance our ability to observe, measure, and estimate parameters of rainstorms (such as, rain rates, hail rates, hydrometeor category, raindrop size distributions, 4D precipitation structure) with consequential improvements in the prediction of floods and the management of water resources. The modular and cellular structure of the radar observation network would facilitate: i) high flexibility in selecting and changing the critical area for hydro-meteorological monitoring and forecasting, civil protection support and agriculture management; and ii) exploitation of existing cellular-phone radio-base station towers as a mean to use those facilities to minimize the impact of new civil constructions for the radar network infrastructure. In this paper we will present the X-band mini-radar system characteristics in terms of the best tradeoffs between costs and performances for hydro-meteorological applications and validation of precipitation algorithms against in situ observations.

Assessment of a river catchment water balance using RS data: Case study of the Upper Awash, Ethiopia

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It is increasingly recognized that optimal and integrated water management at a river basin scale – addresses green and blue water, requires accurate understanding of the spatio-temporal variability of the key components of the water balance: Precipitation P, evapotranspiration ET, interaction with ground water G, and runoff R. The Upper Awash basin (12,000 km^2), located in central Ethiopia -being the most utilized river basin in Ethiopia is experiencing competing demands over limited water resources,.

This paper presents a detailed water balance validation of the Upper Awash basin. The key components of the water balance (P and ET) have been retrieved from remote sensing data, while runoff is obtained from ground measurements. The monthly ET values for two years (2004 and 2005) have been computed by the Surface Energy Balance Algorithm for Land (SEBAL) using the Moderate Resolution Imaging Spectroradiometer (MODIS) images. The computed ET has been validated against ground meteorological measurements using crop coefficient and reference crop evapotranspiration over selected vegetation covers. The comparison shows good matches for high soil moisture content regions (over the escarpment), and diverges towards the lower flat reaches of the basin associated with low soil moisture content.

The study reveals key information on the spatio-temporal variability of the water cycle over the Awash headwater sources. It shows that the combination of local data, remote sensing and the GIS computation offers an improved understanding and better quantification of the spatio-temporal variability of the water balance components.

Rainfall-Runoff Simulations in Arid Catchments, Sinai, Egypt

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Egypt's Sinai Peninsula falls within an arid climatic belt that crosses northern Africa and southwestern Asia. Despite its aridity, Sinai is occasionally subjected to heavy rainfall causing flash floods, which are commonly characterized by sharp peak discharges with short durations. Several flash floods were recorded in south Sinai, which resulted in significant infrastructural damages, population displacement and, sometimes, loss of lives. Despite their hazardous effects, flash floods in Sinai, and other parts of southern Egypt, represent a potential resource for non-conventional fresh water sources. In order to mitigate flash flood damages and efficiently harvest the flash-flood highly needed fresh water, it is crucially important to accurately predict the occurrence of flash floods in terms of both timing and magnitude. Several studies have been implemented to develop hydrologic models for predicting flash floods in Sinai. In these studies, methodologies that are primarily conceptual, such as synthetic unit hydrographs, have shown little success at reproducing observed flood hydrographs. Physically-based distributed models provide an alternative approach for modeling food events in the Sinai arid environment. This study will examine the utility of a physically-based distributed hydrologic model (Gridded Surface-Subsurface Hydrologic Analysis, GSSHA) to simulate rainfall-runoff response in a small and a mid-size catchment in Sinai. GSSHA is a fully distributed-parameter, process-based hydrologic model that uses finite difference and finite volume methods to simulate different hydrologic processes. The watershed topographic and hydrologic properties are represented using Cartesian grids in the order of 100x100 m2. Overland hydraulic properties and soil hydraulic parameters were varied according to combined spatial classifications of soil type and land use maps. Field measurements of soil types and infiltration parameters were used to initially assign model parameters. The parameters were further adjusted through model calibration against available runoff measurements at each catchment outlet. The rainfall data was collected and compiled from the available rain gauges in the study catchments. After performing calibration runs, sensitivity analyses were highly needed to evaluate the impact of uncertainties induced by parameter estimation and data limitations. The sensitivity analysis focused on the following parameters: overland and channel roughness; and infiltration parameters for overland flow. In addition, hydraulic conductivity and thickness of streambed material were assessed to examine the effect of channel transmission losses. In addition, the effect of the initial moisture content and the spatial variation in rainfall information were considered. The analysis performed in this study yielded fair agreement between GSSHA-simulated hydrographs and the corresponding stream-flow measurements, which indicated the ability of distributed models to better represent spatial variations in model input and parameters that affect rainfall-runoff processes in arid environments. However, the results also indicated significant sensitivity to the selection of model parameters. Furthermore, model results were highly dependent on the degree of spatial variability represented by the limited number of rainfall gauges in the catchments.

Developing Regional Intensity-Duration-Frequency Relationship Maps for Ethiopia: A Case study of Amhara, Oromiya, SNNRP and Tigray Regional States

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The rainfall-Intensity-Duration-frequency (IDF) relationships is one of the most commonly used tools in water resources engineering , either for planning , designing and operating of water resource projects, or for various engineering projects against floods. So far there is only one officially known IDF curve developed by Ethiopian Roads Authority, which represented the country into only four IDF regions.

We developed a regional IDF curves applicable to each Regional States with the intention of developing national IDF curves. Annual maximum rainfall magnitudes of 0.5, 1, 2, 3, 6, 12 and 24 hours durations were abstracted from the automatic rain gauge charts and fitted to the probability distributions to select the best distribution. Accordingly, at-site IDF curves as well as regional IDF curves were finally delineated to each Regional State of Amhara, Oromiya, SNNPR and Tigray. Oromiya is regionalized into 8 IDF regions, SNNRP into 5 and Amhara-Tigray together into 5 regions.

The result of the study is believed to benefit the Regional State in providing basic information's on rainfall intensity, duration and frequency relationships to all water professionals and designers for gauged as well as un-gauged areas of water resources development.

Development and Application of Spatially Parameterized Depth Duration Frequency Model for Estimation of Design Rainfall for Oromia Regional State, Ethiopia

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Depth Duration Frequency (DDF) relationships are currently constructed based on an at site frequency analysis of rainfall data separately for different durations. These relationships are not accurate and reliable since they depend on assumptions such as distribution selection for each duration; they require a large number of parameters, experience intensive equations and regionalization is also very poor and coarse. In this study, scaling properties of extreme rainfall depth series are examined to establish scaling behavior of statistical moments and quantile estimates over different durations. The annual extreme series of precipitation maxima for storm duration ranging from 0.5hr to 24hr observed at network of rain gauges sited in Oromia regional state were analyzed using an approach based on moments. The analysis investigated the statistical properties of rainfall extremes and detected that the statistics of the rainfall extremes follows a power law relation with its duration. Moreover, the variations of the distribution parameters with durations of annual maximum rainfall depth series were explored and found that the logEV1, EV1 and logistic distribution parameters exhibit a power law relationship with durations. Following the analysis, scale invariance of extreme rainfall depth series is investigated and dissipative (multiple scaling) nature of extreme rainfall depth series is considered, thus introducing a general distribution free framework to develop Depth Duration frequency (DDF) model. A Depth Duration Frequency (DDF) model with gridded set of parameters is developed for estimation of point rainfall frequencies for a range of duration for any location in Oromia national and regional state. A DDF model was fitted to series of annual maxima and its parameters were determined by a least squares method and these parameters were interpolated and mapped on a 1km grid. The model allows for a parsimonious and efficient parameterization of DDF relationships, and its performance is shown to improve the reliability and robustness of design storm predictions as compared with those achievable by interpolating the quantile predictions of extreme rainfall data for specific durations. Moreover, design rainfall Estimates found from the scaling DDF model are comparable to estimates obtained from traditional techniques; however, the scaled approach was more efficient and give more reliable estimate compared with the observed rainfall depth at all stations.

Copula Modeling of Hydrological Drought Using Proxy Data

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Absence of recorded long time streamflow data hinders a reliable hydrologic drought frequency analysis and understanding of the phenomenon in the past. In this study proxy data from riparian tree rings and ENSO climatic indices are used for reconstructing instrumental streamflow records and analyze the hydrological drought condition in the Wabi Shebele river basin, Ethiopia. The reconstructed annual series is further disaggregated and seasonal hydrologic drought events are extracted using theory of runs. The developed series depicts extreme events frequently occurring in the last three decades. Two-parameter Weibull and two-parameter lognormal distributions fit well the marginal distribution of severity and duration of the hydrological drought respectively. Since the marginal distributions are different, copulas are used to model the dependence structure between the variables. The joint and conditional probabilities of severity and duration of the drought events are determined from these generated data. The dependence between the random variables is accommodated through measure of dependence based on ranks, Kendall?s tau. Among the different families of copula evaluated, Frank copula outperforms well. The parameters are estimated using non-parametric, semi-parametric and parametric procedures and compared using Akaike Information Criterion.

LAND-SAF MSG Estimates of Reference Crop Evapotranspiration in Ethiopia

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According to the FAO Irrigation and Drainage report 56 the Reference Crop Evapotranspiration (ET0) is a parameter playing a key role in the evaluation of water requirements of agricultural crops in irrigated regions. ET0 is determined with a version of the Penman-Monteith equation, using meteorological data collected over non-stressed grass. Unfortunately, weather stations where these data are gathered are rare in most semi-arid regions. Moreover, their maintenance is expensive and labour consuming. For that reason there is a need for cheap and reliable alternative methods to map ET0. Our study concerns a LAND-SAF project aiming for an approximate method to determine ET0 from images of the European geostationary satellite MSG (METEOSAT Second Generation). More precisely, the products developed in the context of the Land Surface Analyses Satellite Application Facility, and sponsored by EUMETSAT, will be used. Because ET0 is linked to the concept of potential evapotranspiration the MSG-derived ET0 will be suitable as input parameter in hydrological models. Furthermore, ET0 can be used for filling gaps in time series of actual evapotranspiration estimates (ET) obtained from remote sensing techniques using satellites with high spatial, but low temporal resolution, such as LANDSAT. Gap filling is particularly important when cloudy conditions occur. The validation of the proposed ET0-MSG method will be presented as well as some first ET0-MSG maps for selected regions in Ethiopia and South Africa.

Land Surface Energy Fluxes: A Reflection of Vegetation Dynamics and Land Management Under Different Latitudes

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Energy fluxes are important components of the land-atmosphere processes governing the rate and amount of water movement between the same. These fluxes are highly spatiotemporal variable dictated by various factors including land cover, available soil moisture/water, meteorological parameters (solar radiation, wind speed, vapor pressure) and also topography. Understanding the energy fluxes as a function of landscape physical properties, topography, land management for different latitudes is essential in estimating the water-energy exchanges between the land surface and atmosphere. This study presents the estimation and evaluation of latent and sensible heat fluxes for three different latitudes as a function of fractional vegetation cover and topography. The study areas are the Mara River basin (17°24'53"S, 32°2'10"E) in Kenya/Tanzania; the Kissimmee River basin (27°44'42"N, 81°14'43"W) in Florida of the United States (USA); and the Glacial Ridge wetland (47°41'25"N, 96°16'53"W) in Minnesota of USA.

Microtopography can regulate soil moisture content and its spatial distribution. The role of topography in the redistribution of moisture and hence energy fluxes is presented. Remote sensing-based surface energy balance approach was used in estimating energy fluxes from Landsat and MODIS images. The effect of fractional vegetation cover on the energy fluxes were also evaluated and analyzed. The use of energy fluxes in evaluating success in environmental restoration of wetlands in Florida and Minnesota and also in understanding the onset of drought and hence wildlife migration in Kenya/Tanzania is evaluated. The results indicate that vegetation controls the partition of energy fluxes, depending on latitudes.

Long-term Measurements of Carbon, Water Vapor, and Energy flux from a No-Till Field

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In the past, intensive agricultural practices have greatly increased crop production and food supply in the world. However, future intensification of agriculture as business as usual practice may become questionable. Experimental data necessary to understand both the influence of key environmental variables and soil management practices of intensive agriculture and atmospheric CO_2 are limited. The objective of this study is to examine the soil-atmosphere carbon exchange of winter wheat/soybean cropping systems for northern Alabama soils under a no-till system. The daily, seasonal and integrated sum of net ecosystem carbon exchange was determined using 7500 open path IRGA and CSAT. Preliminarily data indicate that the seasonally integrated CO_2 exchange (net ecosystem production, NEP) winter wheat/soybean canopies exhibited marked difference with soybean crop fixed more carbon than winter wheat canopy. Overall, the typical daily NEE in rainfed soybean ranged from - 10 to -25 $\mu molm^{-2} s^{-1}$ and - 18 to -30 $\mu molm^{-2} s^{-1}$ in 2007 and 2008, respectively. The longest diurnal carbon uptake rates were observed during the warmer months (May to August) although the summer of 2007 was one of the driest periods in northern Alabama in more than 150 years. The cool season winter wheat crop gained daily maximum NEE values ranged from - 4$\mu molm^{-2} s^{-1}$ in January to -12.5 $\mu molm^{-2} s^{-1}$ in March of 2007. The spatial integrated ecosystem C magnitude and detailed results of our study will be presented.

Principles of Irrigation Management

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Irrigation is a social technology. Based on observations of irrigation systems around the world over several decades, the following principles have been observed to be important:
The Principle of Compatibility
The Principle of Sustainability
The Principle of Manageability
The paper will expand on these Principles with examples, together with a summary of their cumulative effect.

Effect of mulching and irrigation application on water use efficiency and productivity of pepper

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Water scarcity remains to be the main limiting factor in intensifying agricultural production in arid and semi-arid climates. Hence optimum utilization of the available water needs no reminder. This study was proposed and executed to evaluate the effect of different irrigation levels and mulch type on moisture conservation, yield and water use efficiency of drip irrigated pepper. The field experiment was designed as a two factor factorial experiment arranged in RCBD replicated three times. The two factors were three levels of water application (50, 75 and 100% of the CWR) and four types of mulches [white plastic (WP), black plastic (BP), straw (S) and no mulch (C) as control]. The effect of mulch and irrigation level was evaluated in terms of growth and yield parameters (plant height, leaf number, and average branch length, total yield, marketable and unmarketable) and water use efficiency. Moreover, temperature and moisture were monitored using soil thermometer and tensiometer, respectively. It was found that temprature varied with mulch type where the highest temperature was monitored under white plastic mulch followed by black plastic mulch. Soil suction values were generally low for white plastic. The variability among yield and WUE was significant ($p < 0.01$) for both mulch and irrigation levels. Interaction effects were not statistically significant for all parameters except for total yield. The maximum pepper yield (12.457 tons/ha) was observed when full CWR was applied and WP was used as mulch, while the next highest yield (12.292 tons/ha) was observed when 75% CWR irrigation was applied under WP mulch. On the other hand higher WUE was observed when 75% of CWR was applied under plastic mulches. Based on the findings of this research, both black and white plastic mulches are equally effective in soil moisture conservation. When 75% of CWR was applied a 25% water saving was observed without significant reduction in yield.

Modeling of hydraulic structures: Why, When and How

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UNESCO-IHE Delft

Earthquake Induced Permanent Deformation Analysis of Large Embankment Dams in Ethiopia

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This paper presents a fully dynamic analysis of two major embankment dams located in the most seismic part of Ethiopia, namely Tendaho and Kesem dams. Construction of Tendaho dam has recently been completed, while Kesem dam is still under construction. The analysis presented here is the first of its kind in the country and has resulted in significant changes in the original design of Tendaho dam. The principal objectives of a dynamic analysis of embankment dams are assessment of liquefaction potential of susceptible materials and determination of permanent deformations. Results of liquefaction analysis of the dams are presented in another article; and this paper deals with the second objective – earthquake induced permanent deformation analysis. Geological formations of the dam sites, behavior of different materials used for building the dams, and site specific earthquake have been incorporated in the analysis. The dynamic analysis results revealed that in the event of strong earthquake shaking that involves dam crest sliding movements, the originally proposed parapet wall would fail and it would not be able to provide the required freeboard. Therefore, following the recommendations made in this study, the dam crest has been raised by 1.5 m so that the dam will be able to accommodate the total required freeboard including the estimated 70 cm vertical permanent displacement due to dynamic loading. In the case of Kesem dam, the analysis results indicate that the originally designed rockfill dam is safe under dynamic loading.

A New Methodology to Model the Breaching Embankments

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Embankments provide many benefits to the society. They protect people, land, and property from flooding. They also retain water for irrigation and drinking purposes. However, unfortunately, when they fail they introduce a great risk to the communities living downstream. Therefore, emergency plans have to be implemented to minimise the consequences of this failure and its associated risk. The reliability of these emergency plans depends on how accurate the failure of embankments can be modelled.

This paper presents the work undertaken to develop a model that can simulate more accurately and reliably, than other available models, the failure of embankments. The model is based on the principles of hydraulics, sediment transport, and soil mechanics. It employs a new methodology to model the lateral growth of the breach based on a combination of continuos erosion and mass instability. The model can simulate the failure of different embankments, either homogeneous or composite, by overtopping or piping. The model was tested using experimental and real failure data. Model results are in agreement with the observed values. The model also showed a better performance in comparison with other breach models.

Long-term effects of watershed management on surface runoff and sediment loss in the Ethiopian Highlands

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Data on rainfall, runoff and sediment loss from different land use types have been collected by the Soil Conservation Research Programme in seven small catchments (73-673 hectares) throughout the Ethiopian Highlands since the early 1980s. Monitoring was carried out on a storm-to-storm basis for extended periods of 10-20 years, and the data are analysed here to assess long-term effects of changes. Soil and water conservation technologies were introduced in the early years in the catchments in view of their capacity to reduce runoff and sediment yield. Results indicate that rainfall did not substantially change over the observation periods. Land use changes and land degradation, however, altered runoff, as shown by the data from small test plots (30 m^2), which were not altered by conservation measures during the monitoring periods. Sediment delivery from the catchments may have decreased due to soil and water conservation, while runoff rates did not change significantly. Extrapolation of the results in the highlands, however, showed that expansion of cultivated and grazing land induced by population growth may have increased the overall surface runoff. Watershed management in the catchments, finally, had beneficial effects on ecosystem services by reducing soil erosion, restoring soil fertility, enhancing agricultural production, and maintaining overall runoff to the benefit of lowland areas and neighbouring countries.

A simple sediment loss model for the Ethiopian Highlands

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The hydrology of the Nile basin is typical for a monsoonal climate with the amount of runoff increasing for a given storm as the rainy season progresses. The sediment concentration does not follow the same trend with sediment concentrations peaking before the discharge peak. This makes modeling sediment loss a challenge. The objective of this paper is develop and test a simple loss model for the Ethiopian Highlands that can predict realistically daily sediment losses. Our sediment is linked with a distributed hydrology model in which the overland flow is generated on both the saturated bottom lands and the degraded hillslope areas. The remainder of the hillslope areas are permeable and are the source of the interflow and the base flow in the river. The sediment models assumes that in the river all interflow and base flow is sediment free and the surface runoff is the source of the sediment and mainly from the degraded areas and to a lesser extent from the saturated bottom lands.

The model was tested with observed sediment concentrations from three small SCRP watersheds (Anjeni, Andit Tid and Maybar) and that of the whole Blue Nile. For most of the years with good quality sediment data the model could predict the daily sediment concentration with a regression coefficients in the order of 0.5-0.6. Nearly the same model that was used for predicting the sediment loads in the small watersheds for predicting the sediment concentration of the whole blue Nile Basin the Blue Nile outlet with equally reasonable results. Our findings suggest that that surface runoff and erosion are likely confined to localized areas in the watersheds not exceeding 20-30% of the total areas. However before it can be generally accepted, it still need to validated with field research.

Erosion, Sediment and Sedimentation Characteristics and Impacts Watershed Management in Blue Nile Basin

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Upper Blue Nile Basin is characterized by High population pressure, improper land-use, over-dependency on agriculture as source of livelihood and extreme dependence on natural resources are inducing deforestation, overgrazing, expansion of agriculture to marginal lands and steep slopes, declining agricultural productivity and resource-use conflicts in many parts. On the other hand the basin is endowed by high hydropower potential (in Ethiopia) and agricultural potential (in Ethiopia and the Sudan) and if the water resources is managed through improved practices without causing significant harm to the further downstream, it can contribute to poverty reduction, environmental rehabilitation and regional growth. The rainfall, runoff and sediment are highly variable both in time and space and meaningful development requires arresting the variability. Furthermore, increased land degradation from poor agricultural practices, erosion and ultimate siltation problems will reduced water quality in the river basin, operation and management of reservoirs. This paper schematizes the Blue Nile Basin (BNB) at various spatial levels as micro watershed, watershed, sub-basin to basin. It looks the development potential with respect to consumptive and non consumptive users of water. It also looks in to the sediment-rainfall-runoff characteristics, their ultimate depositional characteristics and impact in the hydraulic infrastructure in the Basin. The paper also provides impact of various watershed wide impact at the basin level. In order to analysis and quantify these various methods including statistical analysis and modelling under SWAT environment are used.

Impacts of Integrated Watershed Management on Livestock Water Productivity

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In Sub-Saharan Africa, growing demands for water, climate change and environmental degradation aggravate water scarcity and competition for water between various sectors. Livestock keeping is an important livelihood strategy for smallholder farmers in Africa, but one of the major consumers of water. Current low returns from livestock limit its contribution to livelihoods, threaten environmental health and aggravate local conflicts. Mixed crop-livestock farming systems in water scarce areas in Ethiopia exemplify the challenging situation: given the high degree of water scarcity on the one hand and the growing demands for (animal) food on the other hand, there is a strong need to increase (animal) food production without depleting more water and while safeguarding the environment.
In the water scarce Lenche Dima watershed, located in Gubalafto Woreda, Amhara Region in Ethiopia, community based watershed management has been implemented by a past development project. The project aimed to tackle the major problems of the area, including water scarcity for human consumption as well as for crop and livestock production, land degradation and erosion, low crop productivity, livestock feed shortage and low livestock productivity. The project embraced a variety of interventions, directed at different components of integrated watershed management. This included natural resources management, livestock development, crop productivity enhancement, social and income generating activities and community empowerment.

In this study the impact of integrated watershed management on livestock water productivity was assessed. A number of interventions with a clear link to livestock, water and their interactions were selected for investigation. The interventions comprised gully rehabilitation, hillside closure (exclosures) for hay development, fodder tree promotion, water harvesting and small ruminant husbandry promotion.

Livestock water productivity, defined as the ratio of livestock-related products and services to the water depleted in producing these, was assessed at household as well as at watershed scale. A survey was conducted to collect information about cropping patterns, water use, livestock and crop production and socio-economic determinants of households, which did and did not implement the interventions. Land use mapping was carried out based on satellite imagery and field measurements with GPS. The different water flows were assessed based on actual field measurements of rainfall, runoff and soil water content. Evapotranspiration was calculated with the FAO procedures, using crop coefficients. Yield and biomass measurements of the major crops, their residues, tree fodder, hay from the exclosures and the closed gullies allowed to accurately determine livestock feed production.
Results indicated that the interventions each influence livestock water productivity in different ways. Exclosures and gully rehabilitation seemed to be the most promising interventions as they reduce non-productive water flows and in the same time produce more biomass, which is fed to livestock as high-quality fodder. As a result, higher livestock production is reached without depleting more water. Moreover, reduced runoff leads to less erosion and environmental rehabilitation. The strength of integrated watershed management lies in the fact that it combines interventions aimed at different components of the environment and takes into account not only biophysical but also social, economic and institutional aspects.

Using Health Education to Reduce Flood Fatalities

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The adverse human health impacts of flooding are complex and far-reaching: these include drowning, injuries, spread of infectious diseases, and an increased incidence of common mental disorders. Most vulnerable groups to the health impacts of flooding are the elderly, disabled, children, women, and those on low incomes. This paper proposes an intervention strategy based on the Health Belief Model to reduce flood fatalities. The significance of this behavior stems from three facts: (1) structural interventions will not solve the problem, (2) it is not receiving enough attention, and (3) the risk might be on the rise given the rapid urbanization, increased tropical storm activities, and fast population growth in the region. The intervention is anticipated to enhance the public awareness of flood risk in general, which will lead to a reduction in loss of life and property associated with floods, the second deadliest, most costly weather-related disaster.

Long-term Water Quality Assessment, Comprehensive Database Development, and Modeling for Improving Watershed Management: a Multi disciplinary Approach

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A multidisciplinary and integrated Watershed Management research plays a significant role in achieving sustainability in agricultural production as well as improving ecosystem health. A holistic watershed management approach requires long-term field monitoring sites and database development encompassing all physicochemical and biological parameters within the system. The database can be utilized as a scientific tool to identify and prioritize necessary intervention on different watersheds based on the susceptibility of their natural resources to degradation. Lack of information regarding indicators of watershed health and prioritization of restoration efforts are possible factors contributing to the persistence of water quality related problems in a watershed. The water quality program at Alabama A&M University (AAMU) has progressively expanded in the last few years. A comprehensive water quality monitoring and modeling research was launched in 1999 to evaluate the surface water bodies and ultimately develop a watershed management plan for targeted watersheds in Northern part of Alabama. Field data collection was further expanded in 2005 to evaluate the Flint River, Flint Creek, Indian Creek, and Huntsville Spring Branch watersheds. Seven thrust areas were established including: land use/cover analysis; bioassessment of macroinvertebrates as bioindicators, heavy metals, pesticides, nutrients, source tracking (pathogens and non-pathogenic microorganisms) and modeling. Our past research also evaluated the applicability of some of the most popular water quality modeling tools, namely, AQUATOX, BASINS, AnnAGNPS and SWAT models for some of the watersheds. This paper discusses how the multidisciplinary team organized to develop the long term watershed scale database, summarizes our recent research findings, and provides a strategic vision to improve watershed management. Our ultimate goal is to establish and archive a comprehensive water quality database. The database eventually can be used by interested end-users, stakeholders and policy makers to assess the overall health of ecosystem, determine pollution trends within or among water bodies, and identify specific problems in relation to land use and cover changes within these watersheds.

The Effect of Water Physical Quality and Water Level Changes on the Occurrence of Larvae of Anopheles Mosquitoes Around the Shorelines of Koka Dam, Central Ethiopia

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Entomological studies on the effect of water physical quality and water level change on the occurrence of Anopheles mosquito larvae and the formation of larval breeding habitats were conducted in two villages (Ejersa and Kuma) at the Koka Reservoir in Central Ethiopia between August and December 2007. Data on the type and number and physical characteristics of Anopheles larval breeding habitats, species composition and densities were recorded. Meteorological and reservoir water level data were compared with availability of Anopheles larval breeding sites and densities. Four-years retrospective clinical data indicated that the patter of malaria transmission in the village at close proximity of the Koka reservoir is strongly associated with reservoir water level change during the peak malaria transmission season. Data from adult and larval collection showed that Anopheles pharoensis, An. gambiae s.l., An. coustani and An. squamosus were found in the study area in different proportions. An. pharoensis larvae were dominant at the village close by the reservoir while An. gambiae s.l. more common at the second village away from reservoir during the short breeding interval during the study periods. The total count of An. pharoensis larvae breeding in shoreline puddles at the reservoir site was significantly higher than at the control village ($X2 = 942.8$, $df = 1$, $P < 0.05$). This indicates that this species prefers breeding sites created in association with shoreline puddles that provide ideal turbid breeding pools with much aquatic vegetation. The total count of An. gambiae S.l. at the reservoir site was also significantly higher ($X2=200.5$, $df=1$, $P < 0.05$) than at a the nearby control village. Generally, mean larval density of An. gambiae s.l. was higher in slightly turbid and shallow aquatic habitats ($F=16.97$, $p<0.05$ and $F=6.03$, $p<0.05$) than that of turbid and deep aquatic habitats. The density of An. pharoensis in breeding habitats with floating vegetation and with relatively shady condition was significantl! y higher than that of the aquatic habitats with much light and greater emergent vegetation ($F=15.75$, $P < 0.05$ and $F=10.56$, $P < 0.05$). There was also a strong positive correlation between the occurrence of larvae, water temperature of the breeding habitats and daily minimum atmospheric temperature ($r= 0.541$ and, $r= .0.604$, respectively $P <0.05$). There was strong positive association between water level changes resulting in subsequent recession of the reservoir and the number of positive breeding habitats during the sampling period in the reservoir village ($r = 0.605$, $P < 0.05$). Results in this study clearly showed that water physical characteristics such as water temperature, turbidity, depth and vegetation cover play an important role in the species composition, total count and density of Anopheles mosquitoes in the vicinity. Reservoir water level change is also associated with the proliferation of ideal mosquito breeding habitats.

Cholera toxin B (CTB) Congugated Parasite\'s Soluble Egg and Glutathione Transf

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Schistosomiasis is one of the water born parasitic diseases that together with Malaria and Lymphatic Filariasis accounts for 2 billion people risk of infection.Its transmission dynamics is associated with ecological transformations due to water development and management involving construction of dams and irrigation schemes, programs essential for food and energy security.

The disease is a result of T-cell mediated hyper sensitivity reaction around the parasite eggs leading to granuloma formation that cause permanent damage to liver, intestine, bladder and uterus in man. Available drugs can do little to improve once the damage is done. To fill this gap CTB-conjugated SEA and GST antigens were delivered to mice for 3 conseutive weeks post infection. Results showed that both antigens could reduce granuloma size and inhibit cytokines (IL-2, IL-3 and IL-4) involved in the recruitment, development and differentiation of T-cells. These effects were more amplified by the presence of CTB vector. Where as the frequency of antibody (IgG1, IgG2a, IgA and IgE) secreting cells was high and most importantly mortality was significantly reduced in CTB-GST treated infected mice. Over all the findings suggest the possibility for production of vaccines that have anti-parasitic and pathological immunity which consequently improve the morbidity and mortality in mice.

Adapting to a changing world: Implications for water management

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Everyone is aware that the world is changing, and that many of these changes will impact our water resource supplies and how they are used and managed. It's always a challenge to try to predict the future, especially the distant future implied by words such as sustainability.
But one thing is certain, the future environment our descendants will experience will differ from the economic, social, technological and natural conditions we experience today. Some aspects of the changes that are happening may not be under our control, but many are. And to the extent they are, we can help influence that future. In this paper I will attempt speculate about a future some 40 to 50 years from now, and how water will need to be managed then, with the goal of motivating some thinking and discussion about how we as water managers can influence and prepare ourselves (or our successors) for that future.

This theme fits in with the current interest in sustainability, for no matter how it is defined, it makes us think about the long-term future.

How do we develop and manage our natural and cultural resources in ways that benefit both us and future generations of people living on this earth? If they could, just what would future generations tell us today how they would like us to develop and manage our water resources so that they will be better able to meet their needs and achieve their goals as they strive to improve the quality of their lives? And what will be their needs and goals? That is the major challenge in defining what decisions we make might be considered sustainable. Of course it is impossible to know, but here I attempt to identify the challenges and issues water managers could be addressing some 40 to 50 years from now, and what we can begin to do now to reduce them.

Preliminary Assessment of Economic Sustainability of Water Supply Schemes in Rur

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The study consists in a survey and a preliminary analysis of the economic sustainability of rural water supply in Oromyia region, focusing on the evaluation of the economic management of water schemes and investigating tariff strategies. The aim is to provide the WaSH sector in Ethiopia with a methodology for reviewing tariffs and post-project management for water supply in rural areas.

Data for analysis have been collected with site visits and structured interviews to water-committees and district administrations. A quantitative analysis has been carried out by means of the Average Incremental Cost method and by assessing the Break-Even Point achievement of a stratified sample of 67 water supply schemes, respectively considering: O&M, Depreciation and Capital Investment Return. Despite the limited dimension of the sample, the methodology has been proved consistent with the challenging situation of the sustainability of rural water supply schemes. Hence the study offers relevant findings and suggests the promotion of more comprehensive investigations on the same theme across the sector in Ethiopia.

Through a series of ad-hoc analysis for each type of scheme, comparative evaluations among technologies and among implementing approaches, this study highlights the presence of two tariff systems for Simple and Complex schemes (flat and uniform). Generally tariff setting is unrelated with cost-recovery necessities. The water supply O&M cost management is often characterized by subsidies and overlooked expenditures, with implications on sustainability (only 13% of the Simple and 43% of the Complex schemes are found sustainable). Per capita water consumption rates, although difficult to measure, are found lower than expected by development programmes. Moreover the study spurs reflections on the substantial but unclear support provided by authorities to communities, which, within a weak legal framework, often bring to low effectiveness and accountability of WASHCOMs.

Payment for Environmental Service to Enhance Environmental Productivity in the Upper Blue Nile Basin, Ethiopia

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Using contingent valuation method, this study explored the value of irrigation given by households as an initial step towards the development of payment for environmental services (PES). Ultimately, by developing PES, the negative impacts of sediment load on the reservoir and associated irrigation structures will be reduced in the Upper Blue Nile Basin of Ethiopia. Research in this direction is important because soil degradation and sedimentation threaten the livelihoods of many populations in the area. Furthermore, its mitigation measures require continual large investment cost. Therefore, generating new financial sources to sustain environmental conservation is one of the crucial elements required for the sustainability of upstream ecosystem functioning, which ultimately affect both upstream and downstream resource productivity. The research encompasses the analysis of data collected from 190 randomly selected household heads. The first objective of the study is to estimate households? willingness to pay (WTP) to establish PES for the proposed upland soil and water conservation measures. The model results revealed that the aggregate expected WTP for the total of 7,000 hectare of irrigable land was 1,008,000 birr per year with a household utility maximizing price of 49 birr per 0.25 hectare of irrigable land per year and an attached probability of paying the utility maximizing price equal to 73%. The aggregate WTP estimate was found to be greater than four times the project annual government and African Development Fund budget allocation to reduce sedimentation load (upstream soil erosion) by 50% over the past 6 years. The second specific objective is to elicit policy-relevant factors that determine a household?s WTP to assist upland communities for the construction of soil and water conservation practices. The model results reveal that there are about10 substantial variables (both socioeconomic and demographic factors) involved in the willingness to pay for environmental conservation decisions of households. Therefore, incorporating such important variables in policy considerations has a potential to maximize the probability of paying the utility maximizing price of households to increase the aggregate WTP up to 1,372,000 birr. Finally, in view of the results, we conclude that PES has great potential to enhance environmental productivity in the Blue Nile Basin.

Can payment for ecosystem services be applied as a benefit sharing tool in the Blue Nile River Basin? The case of watershed protection

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Benefit Sharing (BS) has come to the forefront of transboundary water in general and in the Blue Nile Basin in particular. It is a new way of thinking by focusing on the benefits derived from the river than the water *per se*. In spite of its theoretical popularity, it is generally hard to implement it on the ground. In contrast to benefit sharing, Payment for Ecosystem Services (PES) is a practical tool which is being applied in several parts of the world. This article therefore argues that payment for ecosystem services can be used as a benefit sharing tool in the Blue Nile. This study adapts its conceptual framework from Sadoff and Grey's (2002) benefit sharing and Wunder's (2005a) payment for ecosystem services. The combined theoretical approach is illustrated and supported by key informant interviews from the Blue Nile Basin. By analysing the watershed protection services, namely protection of soil erosion in Ethiopia and sedimentation control at Sudan's reservoirs, this paper aims to show that payment for ecosystem services can be applied as a benefit sharing tool, albeit with some practical limitations. The results highlight not only the importance of using PES to address transboundary environmental problems but also in quantifying, generating and (re)distributing watershed benefits in Ethiopia and Sudan.

Land Use Guided & Water Based Development Approach to Insure Sustainable Development

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Recurrent drought which is challenging the life of millions of People of the region, the worsening poverty situation and the need for societal transformation forced the Regional Government of Oromia to think strategically to address these issues. The lowland parts of Oromia, which are hit by recurrent drought, marginalized and unaddressed areas of the region, are found to be of good development potential areas if solutions to some very limiting factors, mainly water, are given. It is believed that the so called 'food insecure' areas can be changed to food surplus areas and even to development centres that relieve the pressure on the highly pressurised highlands. In addition to this intervention in these areas believed to ensure equity and balanced development in the region.

To this end the development corridor approach, which enabled to exercise area based development interventions, was chosen as strategy by Oromia Regional Government to meet set development objectives. To attain this objective water was taken as an entry point and dramatic achievements have been done so far. Water resources assessment projects have been launched to quantify and qualify the available water resources for the sought development. Parallel with these huge activities the Regional Government decided to undertake intensive studies to understand the resources and dynamics of these distant lowlands and degraded and pressurised highlands. Accordingly, integrated land use planning studies are being undertaken in those areas where water resources assessments are being done. Use of combined conventional and modern approach has enabled to cover 25% of the regions in a couple of years and the study is continuing to finalise the study of additional 22% of the region by 2010.

Results of the water resources survey in Borena and the two Hararge zones have revealed the presences of enough water for human and livestock consumption and the study is continuing to make overall assessment to utilize the subsurface water resources for irrigation. In the same manner the semi detailed land use planning studies has characterised each land unit and indicated the best use.

These efforts made in the last three years are elevated to their present stage and initiated valley development program. The program relies on findings of the past three years' experience, interest of the public and the government, integrated land use plan and water resource studies. Guided by the land use plan, areas delineated as agricultural lands but have limitations to be transformed to higher suitability levels will be addressed in this program. Types of interventions are designed mainly following the hydro geological set up of localities, the degree of severity of existing drought problem. Parallel with this valley development program, major problems in the highlands of Oromia, which is linked with population pressure on limited resources, improper utilization, and management of the natural resources will be addressed in accordance to the recommended land use plan.

In general, the starting points for the intent to introduce and scale up valleys development program, which can also be considered as "area based development intervention", is to bring about ever lasting solutions to areas with food security problem and bring about fast economic growth in areas with high irrigation potentials through integrated intervention than applying the sectoral approach interventions.

Planning Water Management for Secure Food Production in Sub-Saharan Africa

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Sub-Saharan Africa is a region with a high population density and fast population growth. Low economic status, poverty and food insecurity characterize the region. Most countries are regular food aid recipients. As the population growth rate is higher than the growth in food production, future conditions may become even worse, irrespective of the potential resources within the region. Land and water resources are quite sufficient to support food production. Only 16.8% (which is about 4% of the arable land) of the potentially irrigable land has been developed for irrigated agriculture. Drainage development is almost untouched and involves only 0.4% of the agricultural area.
In order to get an impression of promising options and possible constraints, with the help of the policy dialogue model PODIUM, this paper analysis the development of water management scenarios to improve food production in the region. Six sample countries – Cameroon, Democratic Republic of the Congo, Ethiopia, Nigeria, South Africa and Sudan – were considered for the analysis. Three water management scenarios were considered: focus on rainfed agriculture, focus on irrigated agriculture and a mixed scenario. The results of the analysis show that, with proper water management approaches, food security in the region is achievable.

An Analysis of Partnerships and Cross-Scale Institutional Linkages in Ensuring I

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The northern part of Ethiopia is well known to be the most populous and dry. Water/ moisture stress is the key challenges in the livelihood of the community. Rainfall in Tigray is highly erratic, and most rain falls intensively, often as convective storms, with very high rainfall intensity and extreme spatial and temporal variability. The result is that there is a very high risk of annual droughts and intra-seasonal dry spells. Average annual rainfall for the region is 500 mm, varying from about 1,600 mm over some pocket central and western areas to less than 300 mm over the eastern escarpment. Highland mixed farming system is the main practice of the rural livelihood of about 83 percent of region?s population on about 60 percent of the total land mass in areas at more than 1,600 m above sea level. Farming households are still at the level of subsistence characterized by a very low level of specialization of production based on environmental and land suitability.

Livestock production is an integral part of the system, but is increasingly being restricted to stall feeding of animals due to scarcity of land. Animal traction is used for land preparation to produce mainly cereals, pulses and oil crops. Despite the prevailing economic water scarcity the region is endowed with a substantial amount of untapped water resources. The surface water resource potential is impressive, but little developed.

Tekeze is the major river basins in the region, having a total catchments area of 8,900,000 ha and an annual runoff of 7.63 kilometer cubed while more than 69 percent of the water is lost as runoff from the mountainous and densely populated highlands (Aquastat 2005). Comparing to the economical irrigation potential in the basin (189,000 ha) the actual irrigated area is less than 7 percent (24,000 ha). Under the regionalization and decentralization policy, several water and agriculture sector institutions, universities and research institutions have been established at federal and regional levels. Currently, several NGOs, CBOs and private firms are involved in the water sector.

The on-going decentralization process is capacitating the regional and lower level more autonomous administrative organs. During the last sixteen years, several water resources development programs were initiated however, due to the absence of a coordinated institutional thinking lens and systemic cross-sectoral platforms their impact was below expectations. The current instability and inefficiency of local (community) participation in the water sector can be mainly explained by the absence of an integrated planning systems and implementation of cross-sectoral and multidisciplinary complex programs to ensure their sustainability.

Multiple Reservoir Operation Using Genetic Algorithm

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Planning and design of water resource systems comprising a large number of reservoirs requires simultaneous optimization for the operation of the entire system rather than to consider the reservoirs separately. This paper proposes a method of optimizing operation of multi-reservoir in the Lake Tana sub-basin (Ethiopia) by applying a combination of models. The reservoir system is set up in the HEC-5A simulation model to guide the releases of the reservoir system. The Covariance Matrix-Adaptation Evolution Strategy (CMA-ES) is adopted for optimizing the reservoir operation rule curve. The integrated model is demonstrated by considering the existing and four scenarios of future development developments. The competing water sectors are irrigation, municipal water supply, environment and hydropower production. Thus objective function is set to minimize the sum of reservoir and lake release deficits and to maximize hydropower generation. The coupled model provides reasonable operation rule curve for single and multi-purpose reservoir. In all scenarios considered in this paper the Lake Tana water level is well above the dead storage level. Under multi-purpose multi-reservoir operation scenario, there are deficits in irrigation water supply mainly for three months (February, March and April) for smaller dams upstream of Lake Tana.