Proceedings: Modeling and Managing Watersheds Workshop

September 13-16, 2011

Kigali, Rwanda

Proceedings compiled and prepared by Jane Carter Ingram of the Wildlife Conservation Society, cingram@wcs.org[1]

Executive Summary

The Wildlife Conservation Society and the United States Forest Service jointly hosted a workshop on "Modeling and Managing Watersheds" that was held in Kigali, Rwanda on September 13-16, 2011 with generous supported from the United States Agency for International Development and the United States Forest Service. This workshop represented an opportunity to convene watershed and natural resource managers working throughout 15 African countries to share experiences, exchange knowledge, and receive training in novel approaches and tools for analyzing and managing watersheds and the ecosystem services they provide.

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The four day workshop consisted of two parts. The first part (September 13-14, 2011) focused on watershed management challenges in the region, the use of different models and tools for addressing those challenges, and presented results from research undertaken by the United States Forest Service (USFS) and the Wildlife Conservation Society (WCS) on the interactions among land-use, climate, and hydrological systems using ecosystem service models in Tanzania, Zambia, and Rwanda. The scope of these projects, the science behind the models used in the research, and the results of these analyses were presented and discussed among the group with an emphasis on the interpretations of model outputs; management and policy implications of the project results; recommendations for watershed management in each of the countries and river basins including major data gaps that influence decision making; and how similar tools could be applied throughout the region to best support watershed management.

The second part of the workshop (September 15-16, 2011) was more technical in nature and focused on providing training to a smaller group of workshop participants on the use of different approaches and tools for modeling the impacts of land-use practices on water quality and quantity, specifically on the use, interpretation, and application of the Water Supply Stress Index-Carbon and Biodiversity (WaSSI-CB) model, the Integrated Valuation of Ecosystem Services and Tradeoffs (InVest) model, and Artificial Intelligence for Ecosystem Services (ARIES) model. Participants had the opportunity to run the WASSI model on their computers, run various scenarios of change and present their results to the group.

Workshop Objectives

The research project and this workshop aimed to support watershed management and conservation in the case study sites and throughout the region by:

- Addressing how land-use (i.e. forests) and land cover change affect water quality/quantity in the research sites and region;
- Assessing the utility of models and research results to inform watershed management and policy in the research sites and region;
- Identifying major research and knowledge gaps with respect to watershed management throughout the case study sites (through on-going research) and region (through the workshop);
- Strengthening the capacity of watershed managers to integrate, use, and interpret different types of data/information to assess how water resources may be affected by climate and land-use and to identify potential management responses to current and future stressors/changes in water resources;
- Identifying opportunities, such as Payments for Ecosystem Services, for strengthening conservation and watershed management.

Summary Points of Workshop

- Major threats to water resources throughout the region include climate change, the growth of populations that increase the demand for water, and land-degradation leading to erosion that causes sedimentation and siltation of water sources, as well as, contributing to landslides and flooding. Sedimentation and siltation of water ways can cause problems for human health, biodiversity, and economic growth. For example, high amounts of sediment in rivers can clog/damage turbines and, thus, present a major problem for the operations of hydro-power plants.

- Results from the models used in the preliminary research projects indicate that temperature increases will decrease stream-flow (also referred to as run-off or water yield) across the case study sites in Rwanda, Tanzania, and Zambia.

- Forests use water, so, forested areas may result in lower water yield than cropland, for example, but in some areas, they may still yield relatively high amounts of water, over the long-term, when compared to other land-cover types. However, these findings were nuanced across the case studies (so see specific case study messages below) because factors that determine water yield are complex so the relationship between stream flow and land-cover will be contextually specific. For example, because Nyungwe National Park has high precipitation and relatively low temperatures, it may yield more water than a forest with similar amounts of precipitation but higher temperatures.

- Forests in all of the watersheds are very important for controlling soil erosion and sediment loss across the three study sites as the models have shown. Model simulations of deforestation in all countries resulted in an increase in soil erosion and sediment loss into waterways. This suggests that forests play an important role in regulating water quality throughout the region.

- Representatives from water resource management authorities, such as the Basin Authority for the Lake Kivu and the Ruzizi River, must meet goals related to water quality and water quantity so land-use management practices must aim to optimize for both. Water quality and quantity are important for meeting the many uses of water for people and wildlife throughout the case study countries and region.

- Reliable, consistent, and up-to-date data on stream flow and sediment loss are lacking generally throughout the countries in the region, including Rwanda. This data is urgently needed to inform the development of large infrastructure projects like hydropower plants on Lake Kivu.

- Major challenges to watershed management and policy throughout the region include a lack of high quality data on water quality and water quantity, lack of coordinated monitoring stations/equipment, and a lack of coordination among stakeholders,

Specific Messages for Each Case Study Site

Nyungwe National Park, Rwanda

- The modeling results suggest that, due to global climate warming and resultant temperature increases, streamflow (or water yield) appears to have decreased across Rwanda.

- Nyungwe National Park has relatively high water yield (30-40% of annual precipitation).

- Nyungwe National Park has low sediment yield, but deforestation could cause serious sedimentation problems due to high rainfall and steep slopes (as seen in other watersheds dominated by croplands).

- More data and monitoring are needed to estimate water balance and sediment loading and to improve and validate the WaSSI and InVEST models and reduce uncertainty. In particular, it will be important to parameterize evapo-transpiration models and the Universal Soil Loss Equation.

- WaSSI and InVEST and models are useful tools for identifying priority watersheds for conservation and management. Site specific data are most useful for model predictions.

- Next steps of the work here will involve validation of the models and inclusion of the Burundi part of the park within the analyses.

Ruaha Landscape, Tanzania

- Future climate change, such as increased temperature and reduced precipitation, could considerably reduce water yield or runoff in the Great Ruaha River region.

- In general, conversion of forest land to cropland could reduce runoff in some areas and increase runoff in others, but any increase in runoff will not be sustained over time.

- In general a conversion of forest land to agricultural land will increase the amount of sedimentation.

- As land-use activities are managed inside the Ruaha National Park already, the area of focus for any changes or policies in relation to land management should be in the watersheds outside of the park.

- Next steps here are to validate the models and develop more realistic scenarios of change (i.e. simulating the real pressures on water supply in the region rather than the scenarios that were developed for other sites). Currently, participants with experience in the area, thought that some of the results might be misleading from a policy perspective, so, future scenarios need to be changed.

Luangwa Valley, Zambia

- Increases in air temperature and decreases in precipitation will decrease run-off in the region.

- Conversion of forest to crop land will have minimal impact on stream flow given current knowledge of leaf area index and how it might change as a result of agricultural conversion.

- Deforestation in the watershed will greatly increase both soil erosion and sedimentation of waterways.

Important Next Steps Identified Within the Meeting:

- The models and results from the research conducted by USFS and WCS need to be adjusted to reflect feedback from participants on the assumptions made and conclusions reached in each study.

- Policy briefs for each country based on results and technical reports are needed once the adjustments have been made.

- Community of practice established on Frameweb for continued dialogue and technical support.

- Web-site where all proceedings, papers, monitoring resources, and globally available data sets can be found.

- Funding proposals and future support are needed for:
  - State of the Nile Basin Report
  - Further technical training
  - Regional, coordinated water quantity and quality monitoring program

Contents

Detailed Proceedings of the Meeting

The major discussions convened at the policy and results dissemination meeting from September 13-14, 2011 are captured in the following proceedings. Complete presentations for each session included in the agendas (found in Appendix 3) can be found at http://rmportal.net/library/content/translinks/2011/wildlife-conservation-society/translinks-workshop-on-watershed-modeling-and-management.

Introduction to Different Regional Lake and River Basin Initiatives

The Nile Basin Initiative

Mrs. Francoise Kayigamba of the Nile Basin Initiative (NBI) described the initiative, which is a collaborative initiative among nine countries, including Sudan, Ethiopia, Kenya, Uganda, Rwanda, Burundi, Egypt, and the Eastern part of Democratic Republic of Congo, with Eritrea as an observer. The NBI was created in 1999 and includes 3.2 million km^2, but only 7 large dams are included in this area and these are mostly in the north (near Sudan and Egypt). Major tributaries in the region are generated from mountain rain forests, which are the last remaining in Africa, and are thought to be the water towers that source the Nile River. Major threats to water resources in the river basin result from climate change, environmental destruction, and population growth. In Uganda, Tanzania, and Kenya, freshwater availability per capita is decreasing, which indicates water stress throughout the region. Yet, growing populations throughout all of the Nile Basin Initiative countries require water to meet their needs. The NBI is comprised of two initiatives: 1) The Shared Vision Program and 2) The Subsidiary Action Program, The Nile Equatorial Lakes Subsidiary Action Program (NELSAP). NELSAP's mission is to contribute to the eradication of poverty, promote economic growth, and reverse environmental degradation in the Nile Equatorial Lakes region through facilitating pre-investment planning (though institutions and projects) and resource mobilization. It addresses development issues in the NEL Region in two key areas (i) Natural Resources Management and Development and (ii) Power Development and Trade. The value that NELSAP adds to the region includes facilitating cooperation among countries, all of whom have very different capacities; providing a vehicle for consensus, consultation, and cooperation in Nile development projects; sstrengthening economic growth and reduction of poverty by identifying and preparing investment projects for the development of shared water resources; facilitating multi-country agreements for investment financing and for future management through national agencies; promoting 'beyond the river' cooperation in areas such as agriculture and trade; expanding existing regional frameworks; supporting regional and sub-regional cooperation programs on regional water infrastructure; supporting monetary and financial cooperation and integration; and supporting cooperation in regional public goods. Challenges at the NELSAP level include conflicts affecting participation and co-ordination (this affects participation and capacity); legal recognition; broadening participation among Water Resource Managers and conservationists working in similar areas throughout the region (i.e. Mt. Elgon and Nyungwe); financial sustainability so that they don't have to depend on donor funding; availability and reliability of data, which is currently insufficient for environmental and social decision making; and institutional arrangements at the country level for sharing data. As part of the Shared Vision Program (SVP), which aims to build trust, capacity and an enabling environment for investment in Nile Basin countries, the NBI established Decision Support Systems (DSS) at the regional scale and national scales. A data sharing protocol has been signed by the NBI members and, in each country, they are training members on how to process data and how to fill in data gaps. In Rwanda, the national DSS is hosted by the Ministry of Natural Resources (MINRENA). Antoine Niragire presented on the use of the national DSS in Rwanda to model water availability and to inform decisions over water resource use management, particularly the development of hydro-power plants, in the Nyabarongo River Basin in Rwanda. Mr. Niragire has used time-series data on climate (precipitation and temperature), water flow, and land-use data to assess the amount of water available for different uses in Rwanda, particularly hydro-electric power, and how water demand might change in different areas as a result of population growth and demand from the agricultural sector. His case study suggests that there is enough water available for hydro-power development in the Nyabarongo River Basin in Rwanda. However, after 1989, there are considerable data gaps and the pre-1989 data is what has been used to create the scenarios of the future. Thus, as discussed throughout the workshop, it will be important to revisit these scenarios since more recent data collected by the USFS through this project, shows that temperature increased in Rwanda in the 1990s and this has likely affected water-flow and, thus, water supply in the country. Climate change combined with population growth could mean that less water is now available for hydro-power projects, livelihoods, and other uses.

Figure 1. Map of the Nile Basin Initiative Countries

Basin Authority For The Lake Kivu And The Ruzizi River, Claude Kayitenkore

The Lake Kivu and Ruzizi River Basin is a sub-basin of the Lake Tanganyika Basin, which is itself a sub-basin of the Congo River Basin. Two international River Basin authorities already exist: the Commission Internationale du Bassin Congo-Oubangui-Sangha (CICOS), covering the entire Congo river basin, and the Lake Tanganyika Authority (LTA) covering the Lake Tanganyika sub-basin.

Figure 2. Map of the Lake Kivu and Ruzizi River Basin

The Ruzizi cascade, where several hydro-power plants are to be operated in a coordinated way, is dependent upon a multi-national reservoir, Lake Kivu. The Lake supports a range of important economic and livelihood activities. All of the dams for hydro-electricity that are being developed will depend upon this lake. Thus, it is important to conserve water quality and quantity so as to meet the needs of multiple users of the lake's water resources, including hydro-electric power plants. For these reasons, a water basin management authority for Lake Kivu and Ruzizi River is needed to coordinate all of the different uses of water resources. An international convention will be signed between Democratic Republic of Congo, Rwanda, and Burundi, which will establish a stable, legal framework for water uses and will stipulate how water resources are shared and jointly managed. The Lake Kivu and Ruzizi River Basin Authority objectives are to ensure that water quality and water quantity are maintained within the Lake Kivu Basin and the Ruzizi River Basin. A major emphasis is on the protection and conservation of the ecosystems within the basin, in addition, to overseeing how gas extraction influences water quality, and how hydro-power is influenced by and influences water quantity.

The current structure of the Lake Kivu and Ruzizi River Basin Authority is a transitional structure for the management of the water resources and the basin. It is anticipated that the convention will be signed and will be operational by January 2012.

During the discussion, participants asked about the declining water levels of Lake Kivu, which has been an issue for a while, particularly from 2000-2004. The Lake Kivu and Ruzizi River Basin Authority representatives carried out a study to simulate the levels of Lake Kivu and the results of the simulation showed that the levels of water in Lake Kivu depend on two things: 1) climate change and 2) how much water leaves the lake, specifically, through the amount of water leaving Lake Kivu to go to hydro-power plants and evaporation during the dry season. It is clear that during the dry season, water levels will go down, but will go up again during the wet season. Currently, the Lake Kivu and Ruzizi River Basin Authority representatives are wondering if a dam could regulate the levels of water coming out of Lake Kivu, but this has not yet been used for management here. It is important to regulate the amounts of water to maintain an acceptable level and, so, the hydro-power plants are coordinated so that they all can operate. However, resource mobilization and coordination may be challenging, since some of the hydropower plants are managed by a private company while others are a result of public-private partnerships. There will also need to be coordination among other river basin authorities, which is already happening between the Lake Tanganyika and Lake Kivu Basin Authority, for example.

Challenges within the Research Sites: Water Resources and Watershed Management

Rwanda

The population density of Rwanda is 380 persons/km^2, the highest in Sub-Saharan Africa. Intensive farming on hill-slopes has degraded the agricultural land, resulting in soil losses of 20 to 150 t ha y^{-1} on 15 to 50% of the cultivated slopes. People have been converting forests into agricultural lands on slopes that are greater than 48%. Common guidance suggests that farming on a slope greater than 20% is risky, so, farming on slopes greater than 48% is especially concerning with respect to erosion and, potentially, landslides and flooding.

Losses of sediment and nutrients as a result of farming on steep slopes can cause declines in downstream water quality, soil fertility, and drives expansion of agricultural into marginal areas and forests. These problems are exacerbated by climate variability and climate change, which may contribute to extreme weather events and flooding. Despite the considerable efforts that have been undertaken to control soil erosion in Rwanda, adoption of Soil and Water Conservation (SWC) practices have been minimal and loss of fertile topsoil continues. One of the reasons for low levels of SWC practices is the top-down approach that has been taken, which has neglected socio-economic and biophysical characteristics. For example, some of the advice on implementing SWC practices has been beyond the farmer's technical and financial capacity.

However, there have been a few success stories and a variety of initiatives have been implemented effectively. For example, terraces can be a good soil conservation measure and have been used in some places throughout the country. Agro-forestry is helping control soil loss in some places and crop intensification programs are helping to increase crop production and productivity, thereby, decreasing agricultural expansion into other areas. A "One cow per family policy" has recently been introduced, but it is important to consider the sustainability of this policy with respect to sourcing adequate amounts of fodder to feed so many cows.

To improve soil and water conservation in Rwanda it will be important to: develop and use new tools that can be scaled up/down and integrated with socio-economic tools; adopt improved energy sources such as solar panels and biogas for cooking; provide training on improved charcoal production and development of improved stoves; development and implementation of regulations and laws tailored to the scale of the watershed; natural resource governance across ministries; and the development of Payments for Ecosystem Services (PES). All of these things need to be developed as integrated solutions.

The Luangwa Valley, Zambia

The Wildlife Conservation Society has been working in the Luangwa Valley of Zambia for 25 years where they have worked with communities to develop a program called the Community Markets for Conservation (COMACO) program, which provides sustainable sources of alternative income, from farming and other conservation incentives, to families living around the four national parks in the Luangwa Valley.

The Luangwa River is the primary river running through the Luangwa Valley Landscape. The flow of the river is highly seasonal with flows during the dry season (May-November) largely confined to the main channel and during the rainy season (December to April), the river expands and is several kilometers wide, flooding adjacent grassland areas.

The river cuts across 3 national parks and is critical for wildlife. Water resources are also critically important for household purposes such as drinking, cooking, bathing, irrigation (small scale), and transportation. Approximately 9% of water usage in the area is from groundwater.

Management of the river has historically not been regulated. Threats to water resources in the Luangwa Valley include: land use change, severe soil erosion leading to sedimentation of waterways, change in river flows, and pollution from chemical fertilizers used on farmlands. The 2010 Water Resources Management Bill was enacted to address these threats and to provide for the management, development, and conservation of water resources and connected ecosystems. However, significant challenges remain to managing water resources effectively such as the lack of policies on the use and management of water resources; lack of clear rules governing roles of various stakeholders; fragmentation and overlap of mandates of various agencies; and lack of watershed research priorities and technology development.

The Rufiji Basin and the Great Ruaha Catchment, Tanzania

The Rufiji Basin covers an area of 183,791 kilometers^2 and drains into the Indian Ocean. The basin is comprised of four major rivers: the Great Ruaha 85,554 km^2 ; the Kilombero 40,430 km^2 ; the Luwegu 25,288 km^2 and the Rufiji 32,619 km^2 .

The National Water Policy (NAWAPO 2002) sets out the institutional framework at the following levels: National, Basin, Catchment, Sub-catchment and Water User Association. The Rufiji Water Basin Board was established under Section 22 of WRMA No. 11 of 2009 and consists of 10 members. The board has the mandate of: allocating water resources, controlling water pollution, protecting water sources, and handling other general water resources management matters. There are many other actors involved in integrated water resource management throughout the basin.

The major challenges throughout the basin include flooding and droughts. Flooding in some parts of the lower Rufiji Basin have decreased due to damming of the Great Ruaha river. However, water scarcity associated with droughts has caused increased competition for water supplies, which is not sufficient to meet all of the different users' needs. Threats to water resources include excessive water use, with many of these uses being un-authorized, vandalism of monitoring equipment and instruments, environmental degradation, and use of agro-chemicals. In Tanzania, if you want to use water, the law specifies that you have to apply for a water permit. So, those people who have permission to use water are only the people who have permits. For the people who do not want to pay, they must be educated on the importance of having permits for which they have to pay.

The impacts of water scarcity and water quality are far-reaching on the country's economy, human livelihoods, and wildlife. For example, the three major hydro-power plants on the river provide most of the energy to Tanzania. When the river decreases in flow, the hydro-power plants can't produce power. During times of extremely low flow, fishing activities must be halted because fish and other wildlife that are intimately tied to water resources have experienced high rates of mortality.

To address these problems, interventions are underway to better manage water resources. Some of these interventions include construction of dams, borehole drilling for irrigation purposes, restoration of water courses, implementing alternative activities to destructive water resource activities, rainwater harvesting, and training small-scale farmers in the use of water/rice paddy efficiency.

The Use of Models and Other Tools for Managing Watersheds

One of the objectives of this meeting is to encourage people to think about how models could be used for watershed management in the countries of the participants.

Models can be extremely useful for understanding complex systems, such as hydrological systems, but can be mis-used. Thus, before using a model or the results that it produces, it is important to understand the limitations of a model. Models are not reality- they are attempts to represent reality. Models help distill reality into something simple that is easily understandable and can help predict what may happen in the future. Models help explore how natural resources can be better managed to reduce the risk of surprises and to estimate what the economic costs and benefits will be of different management choices. However, because models are only depictions of reality, it is important to remember that all model results are wrong to some extent. But, it is important to ask if the results are wrong by a lot or by a little.

Three major roles of modeling are: 1) prediction 2) experimentation and 3) monitoring. Too often, models are used for prediction only. However, if we are not clear and organized with respect to our knowledge and understanding of a system, such as a watershed, we won't be able to predict what will happen to it. So, we have to experiment. Experimenting also helps us understand what kind of data we need and, thus, what we need to monitor. We need to prioritize what to collect and monitor because with scarce resources we cannot monitor everything. Each of these components of modeling- prediction, experimentation and monitoring- is equally important.

Five major considerations to ask when modeling watersheds:

1. **The Question.** What is the question you want to answer with the model (this is the most important part)?
2. **Knowledge Limitations.** We may have questions we want to ask, but if we don't understand the processes and don't have basic knowledge of the system we are interested in modeling, we won't be able to answer the questions.
3. **Data limitations**. If the data is limited, you will not be able to answer the question accurately.
4. **Time and costs limitations**. If you want the answer fast, don't expect it to be too accurate. For example, time has been limited for this project undertaken by the USFS and WCS, but part of this workshop is to get feedback on results produced so far.
5. **Precision dependent**

As we talk about watershed management issues, we need to make sure that we are talking about the same scale: processes and issues will manifest themselves at different scales. So, spatial and temporal scale is important to consider when using data, developing models, and interpreting results. For example, watersheds in the US are classified and analyzed at different scales.

If you don't have good data, you will not have a good model; data is needed for developing equations; parameterizing the model; and validating the model outputs because models are generally only useful if you understand how well the model works and how well it performs. Thus, data is needed for all stages of model development.

This study undertaken by the USFS and WCS in Rwanda, Zambia, and Tanzania has been exploring the sensitivity of forests to water yield. Specifically, we have looked at stream flow response to watershed manipulation: the way in which water coming out of the watershed changes as a result of reforestation and deforestation. We have used the Water Supply Stress Index (WASSI) model to do this.

When using WASSI, it is important to ask: Can we trust model outputs? And If we can trust them, can we use the models for decision making (if not, they are of limited use)? In order to trust a model, we have to validate it. In places where there is a disconnect between modeled and actual results (for example, the difference between actual and simulated measures of water flow), it is important to look deeper to see why the results differ between reality and the model. The co-efficient of variation (R^2) represents how close the model predictions are to reality: the higher the number, the better the prediction. Once the model has been validated, WASSI can be used to predict water yield (at an annual or monthly scale, depending on your question) and the model can be used to simulate what would happen to water yield under different scenarios. The USFS has used WASSI to create base-line predictions of water stress.. WASSI can also assess how multiple stressors interact together, such as population change and climate change. WASSI can also be used to look at how groundwater will change.

WASSI started out as a water supply stress model, but if you understand water processes in an ecosystem, then you also understand a lot about the productivity and biodiversity of an ecosystem. So, we can use WASSI to look at other elements in the systems and to explore tradeoffs among them. For example, WASSI allows you to ask what happens to water yield when carbon storage increases.

When you are looking at something different, i.e. carbon instead of water yield, you have to go back and validate the model again. Once the model has been validated, it can be used to look at how different scenarios- such as climate change- might affect the model.

During the discussion, a participant mentioned that validation is difficult in Africa where data is lacking, so, often times expert opinion is used in lieu of validation. This is valuable but is considered a type of model *assessment* rather than *validation,* the latter of which is very important. As discussed throughout the workshop, a major challenge in using the results of models like this to inform management practices in Africa, is that there is not enough data to validate the models. So, it would be extremely useful if a monitoring program could be established to foster the collection of the right data at the right scales because currently there is not enough data to make better management decisions.

Modeling Ecosystem Services (Water Quantity and Quality): Overview of WaSSI and Integrated Valuation of Environmental Services and Tradeoffs (InVEST)

The WASSI model allows us to model water yield, but does not allow us to model water quality yet. One of the models used for this study, the Integrated Valuation of Environmental Services and Tradeoffs (InVEST) model, which has recently been developed by the Natural Capital Project, and is still in development, permits modeling and simulation of water quality, carbon, and biodiversity, and other ecosystem services. For this reason, for this project, we have used WASSI and InVEST together.

WASSI was developed in the United States because there are a lot of concerns there about water quantity and carbon. Yet, the problem of water shortage is also a global problem.

Key Characteristics of WASSI:

- The model runs using monthly data: monthly evapo-transpiration data, actual evapo-transpiration data, monthly run-off data, monthly water supply data, and monthly demand data.
- It can be adjusted to various spatial scales.
- The science behind WASSI is a general evapo-transpiration model.

WASSI has been used in a lot of different places with different vegetation types (i.e. Eucalyptus data from Australia that may be useful for Rwanda). Some models are calibrated, some are not- WASSI is not calibrated. Calibrated models are typically designed to look at specific places and, thus, a calibrated model will generally work better for the place where it was developed. However, it can be dangerous if used in another place. Uncalibrated models such as WASSI can be used in more places. WASSI fairly easy to use and, once installed on a computer, can be run with Excel.

For this study, global data was used for climate (but local climate data would be better), land cover data, and Leaf Area Index (LAI), which is available monthly at a global scale. The output of WASSI is "run off", also known as water yield or stream flow, which can also be measured in the field with a stream gauge.

The Integrated Valuation of Ecosystem Service Tradeoffs (InVEST) tool is still being developed and is freely available online at http://www.naturalcapitalproject.org/. We used the sediment retention model in InVEST, but there are many other modules for a range of ecosystem services that can be used. InVEST allows a user to map and value a range of ecosystem services at different spatial scales. The ecosystem service models provided by InVEST are based on production functions that define how an ecosystem's structure and function influence the flows and values of environmental services. The models account for both service supply and the location and activities of people who benefit from services. Because the data needed to create production functions for different services may be scarce in many places, the initial versions of InVEST offer relatively simple models with minimal input requirements. If little site specific data is available, the results of the models are best suited for identifying patterns in the provision and value of environmental services. As with any model, if more data are available and validation is possible, the models will be more useful information for decision making, such as the estimates of the magnitude and value of services provided. Results can be presented in biophysical units or economic values- sometimes you may want to present results in both formats depending on who the decision makers are and what information is most important to them. In some cases, the economic data may not be available and, thus, the biophysical data may be more useful.

In the case of the soil loss/sediment retention model, as applied in this study, InVEST allows the user to map where high sediment flow hotspots are across a landscape. The model not only calculates soil erosion, but also helps the user calculate the costs of removing sediment from the reservoir. InVEST allows the user to create scenarios to explore what would happen if forest is converted to grassland, for example. InVEST looks at an annual long-term mean and, allows the user to run the model for their basin of interest. One limitation of InVEST discussed at the workshop is that it requires ArcGIS software to run and many people throughout Africa do not have access to this software package.

Other models exist for simulating run-off and soil loss, but can be difficult to learn. Both WASSI and InVEST are relatively easy to learn and need relatively little data, which is why they were chosen for this workshop and project.

Research Data and Methods

WCS and USFS had two primary questions for the research project at each site in Rwanda, Zambia, and Tanzania:

1. To model water quantity and sedimentation under current land cover conditions;
2. To simulate how land use management and climate change may influence water quality and quantity.

WASSI

To run the WASSI model, data on monthly temperature, precipitation, Leaf Area Index, and Landcover was required. Monthly records of temperature and precipitation at a spatial resolution of 0.5^{o} by 0.5^{0} from 1960-2009 were obtained from the Climate Research Unit Time Series Dataset from the University of East Anglia. Data on monthly Leaf Area Index (LAI), which is representative of biomass, at a spatial scale of 1km by 1km from 2000-2006 were collected from MODIS Imagery. LAI also plays an important role in evapo-transpiration, with evapo-transpiration increasing with increasing LAI, to a certain point. A landcover map at a spatial scale of 300mx300m from the year 2009 was obtained from

Globcover. See table for more details on where data was obtained.

Data	Spatial Resolution	Temporal Resolution	Time Step	Source
Temperature and Precipitation	0.5° x 0.5°	1960-2009	Monthly	Climate Research Unit (CRU) Time-Series (TS) Dataset 3.1; The University of East Anglia
Leaf Area Index	1km x 1km	2000-2006	Monthly	Zhao et al.,2005; Numerical Terradynamic Simulation Group (NTSG) at the University of Montana Missoula MODIS Imagery, MOD15(FPAR/LAI),
Landcover	300m x 300m	2009	static	Globcover, European Space Agency (ESA), MERIS instrument

InVEST for Modeling Soil Erosion and Sedimentation

We used the Universal Soil Erosion Equation to estimate soil erosion and sedimentation within InVEST. The Universal Soil Erosion Equation is: A = R * K * LS * C * P where A: Average annual soil loss (Tons/ha*yr), R : Rainfall and runoff erositivity, K: Soil erodibility , LS: Slope length-gradient factor, C: Crop and management Factor and P: Support practice factor. For each land class, the research team came up with Cover and Management factors (C) and Practice factors (P) to reflect the potential of soil erosion.

One of the limitations discussed with respect to InVEST is that it has to be run at an annual scale. However, rainfall, erosion and crop cover may vary throughout the year. So, if we could run it monthly, it would be more accurate. For this reason, it may be useful to calculate the Universal Soil Loss Equation outside of InVEST, if possible, because it can be calculated on a monthly basis (or within hours of rainfall data). That may be most accurate in regions where seasons are so extreme.

Results from Three Case Study Sites

Nyungwe National Park, Rwanda

In Rwanda, the project focused on Nyungwe National Park (NNP) and the surrounding area, which is comprised of multiple watersheds (Figure 3).

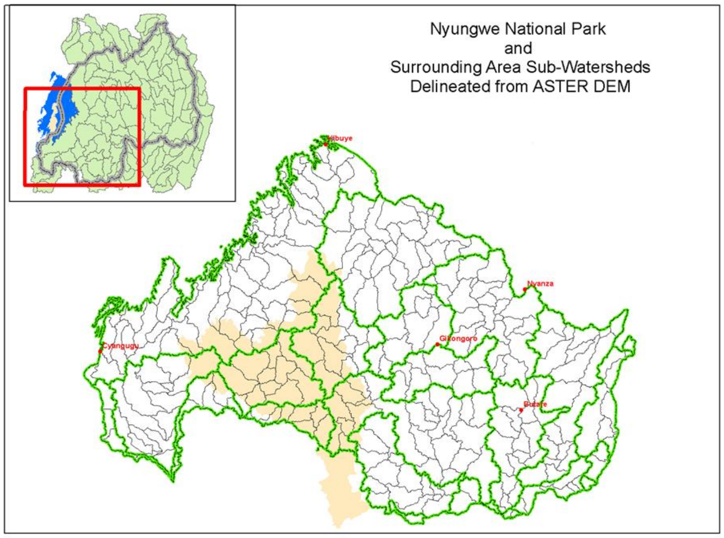


Figure 3: Map of the watersheds in Rwanda. Nyungwe National Park, the focus of this research, is represented in pink.

There has been a large increase in temperature across Rwanda since the 1990s, which is similar to the observed global trends of increasing air temperature (Figure 4). Because temperature exerts a major effect on stream flow, the observed temperature increase across the country is important with respect to water quantity. LAI varies seasonally within the country.

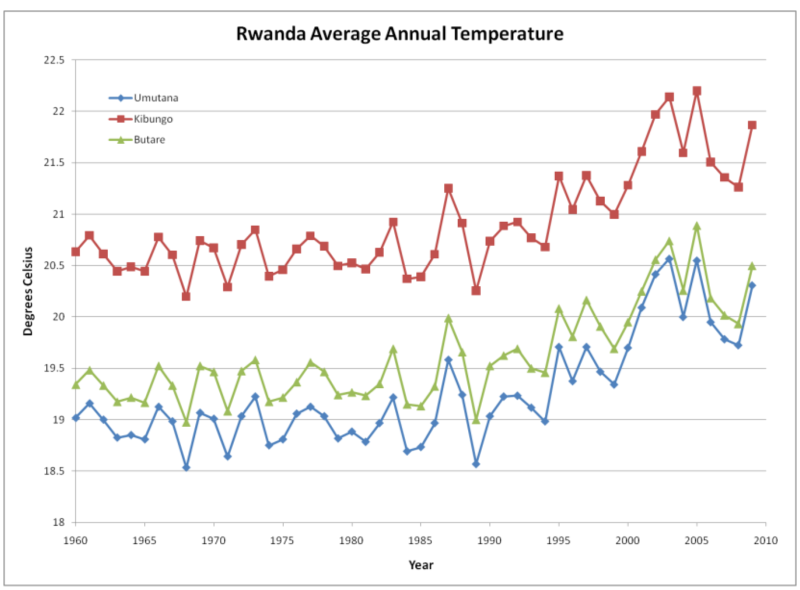


Figure 4. Average annual temperature in Rwanda from 1960-2009. The trend shows that temperatures have been increasing in the past 20 years.

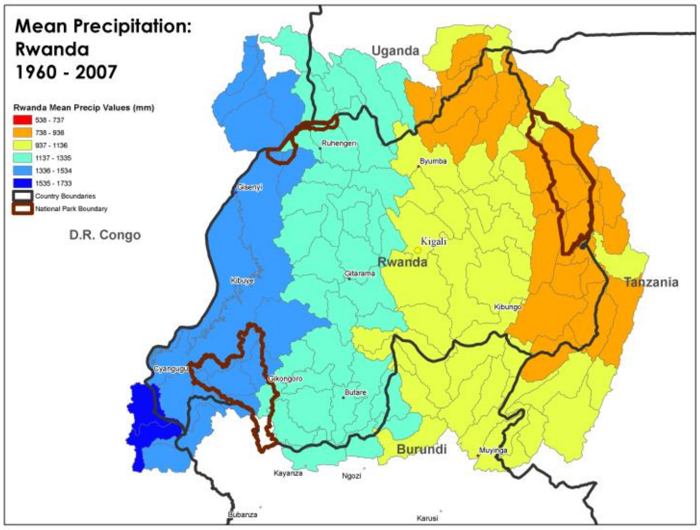


Figure 5. Baseline precipitation gradients across the country.

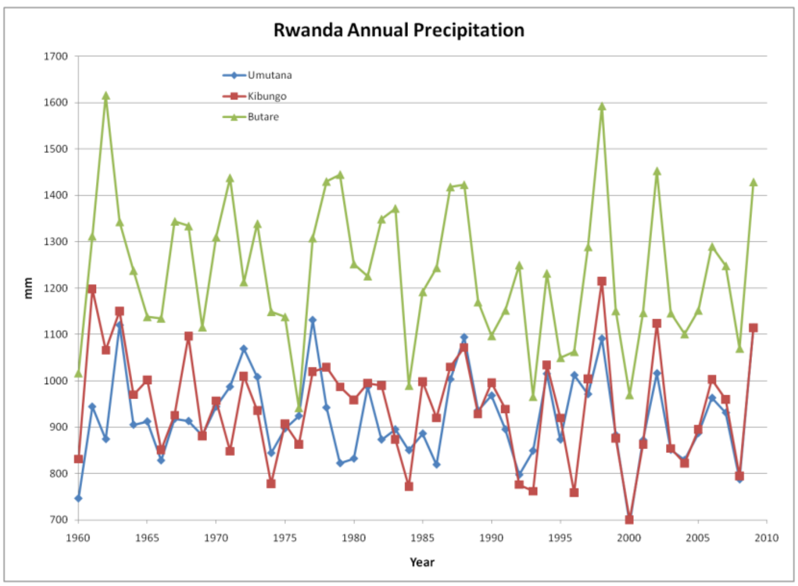


Figure 6: Precipitation trends from 1960-2010.

Modeled Results Using WASSI: The spatial distribution of run-off or stream yield

Models are often used to estimate stream-flow for an entire watershed, which covers an area that can be quite large and, thus, it is difficult, if not impossible, to collect ground measurements at every point along the watershed. For this reason, models such as WASSI are often used to depict stream-flow across a watershed. Ideally, ground measurements of stream-flow would be used to inform model development and/or validate models of stream-flow to ensure the modeled estimates across a watershed are representative of reality on the ground. In this case, because ground data were not available, globally available data on temperature, precipitation, LAI and land-cover type were used to simulate stream-flow patterns across the country. The unit for measuring stream flow is “millimeters” (mm). Using the input data in WASSI to simulate base-line conditions of run-off in Rwanda up to the year 2010, the models showed that about 300mm/year of water is produced by NNP. This is then multiplied by the area of the watershed to get the cubic meters produced by NNP. Because of the high rainfall and low temperature in NNP, less water is used by the forest here than would be the case in forests located in areas with high temperatures and high rainfall. Less than 30% of the rainfall in NNP becomes run-off. In contrast, the percentage of rain that becomes available as runoff in the eastern part of the country is about 15% because air temperature is so high in this part of the country. Using data from 1960-2010, the WASSI model estimated that all of the watersheds across the country are experiencing a decreasing trend in the amount of available water, or stream-flow, which is due to increases in temperature across the country (Figures 7 and 8).

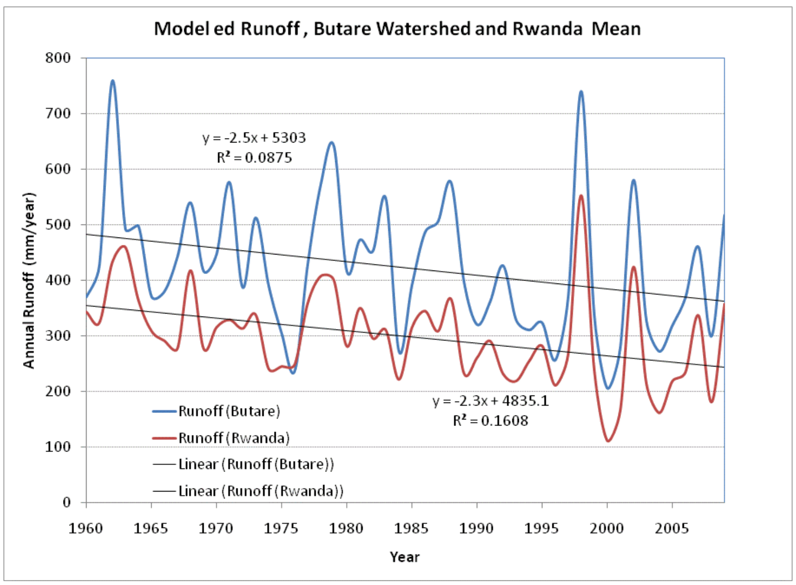


Figure 7. Model simulations of runoff for two selected watersheds in Rwanda from 1960-2010.

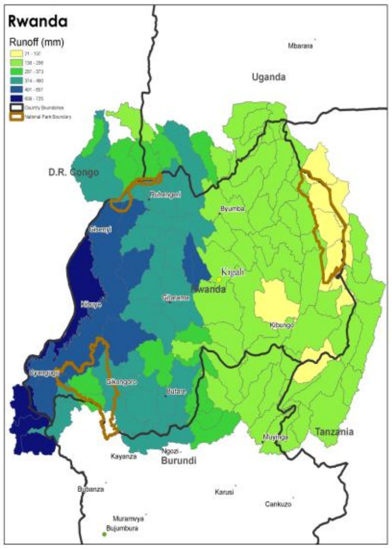
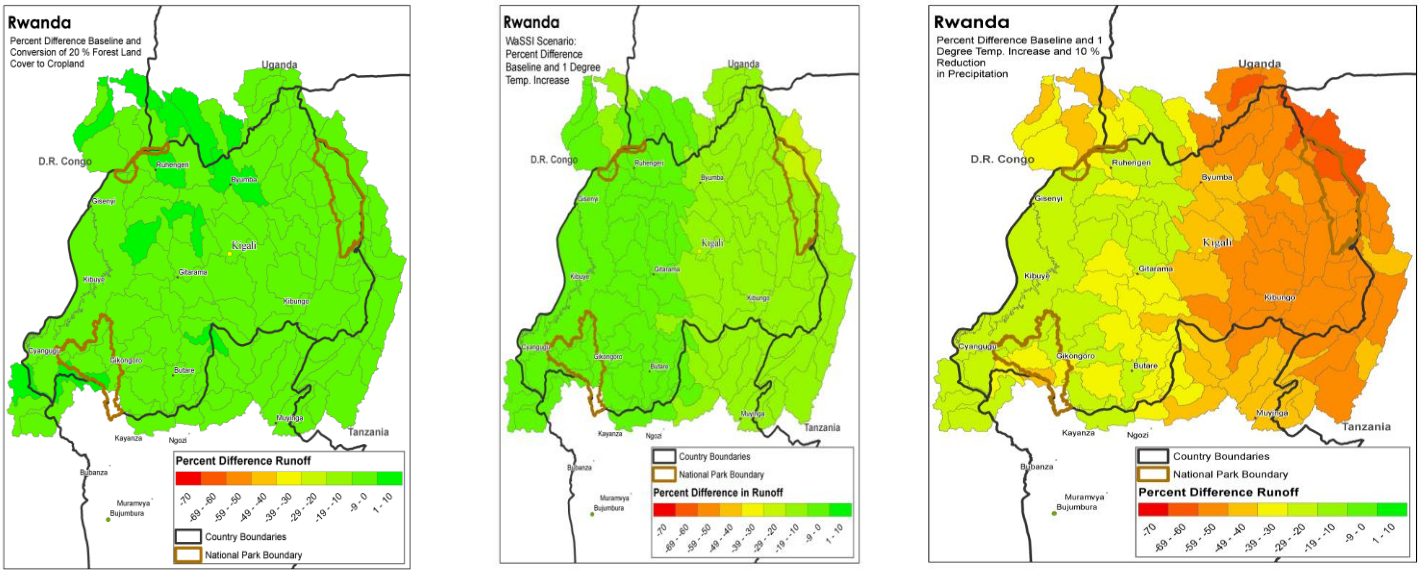


Figure 8. Spatial distribution of run-off across the country as modeled by WASSI.

Using the WASSI model and data collected, scenarios were created to simulate potential future conditions and how these might affect stream-flow. One of the scenarios depicted a 20% increase in deforestation across the country in which 20% of remaining forests were converted to crop-cover. The way in which deforestation impacts water-flow or run-off depends on what the land-cover becomes after deforestation. Some crops have a higher LAI than others and this will influence run-off because LAI plays an important role in evapo-transpiration. In this scenario, the assumption was that forest cover changed to crop-cover following deforestation and crops often have a different LAI than forests- sometimes they will have a lower LAI, but some crops such as banana trees may have a high LAI .So, it is important to be aware of how different vegetation cover types might influence model simulations and actual run-off.

The amount of runoff changed by about 10% when the model simulated that 20% of current forest cover in the country was converted to cropland (the LAI of crop-cover already present in the region were used for the simulations)**.** Another scenario simulated what would happen to run-off if temperature increased by 1 degree Celsius. The results showed that if temperature increased by 1 degree Celsius, run-off would decrease by about 10%. In the scenario in which temperature increased and precipitation decreased by 10%, run-off decreased by about 70%. All of the watersheds are sensitive to runoff if rainfall is reduced and temperatures increase (Figure 9).



9a. **9b.** **9c.**

Figure 9. Percent changes in run-off in Nyungwe when comparing baseline conditions with different scenarios. 9a. The percent different in run-off in a scenario of 20% deforestation (when forest is converted to crop-land); 9b. The percent difference in run-off in a scenario of a 1 degree increase in temperature. 9c. Shows the percent difference in run-off in a scenario of a 1 degree increase in temperature and 10% reduction in precipitation.

Using basic input data needed for the Universal Soil Loss Equation, the baseline of sedimentation and soil loss for NNP was assessed within InVEST. The baseline model showed that within NNP, erosion rates are very low, but outside of the forest, erosion rates are much higher, suggesting that forests are playing an important role in controlling soil loss (Figure 10).

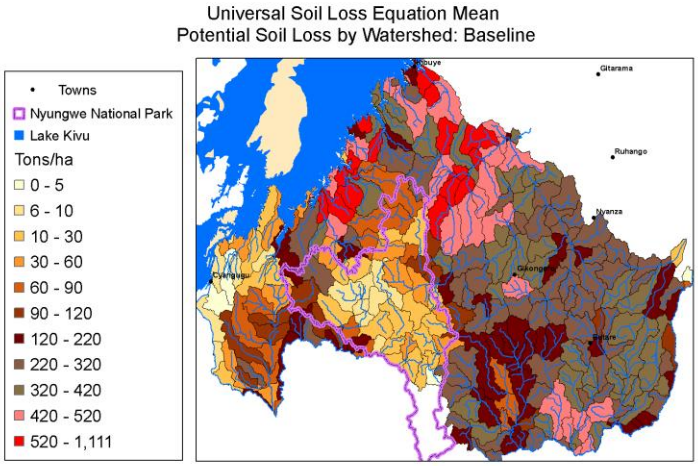


Figure 10. The amount of soil loss under baseline conditions. Nyungwe National Park is demarcated with purple boundaries.

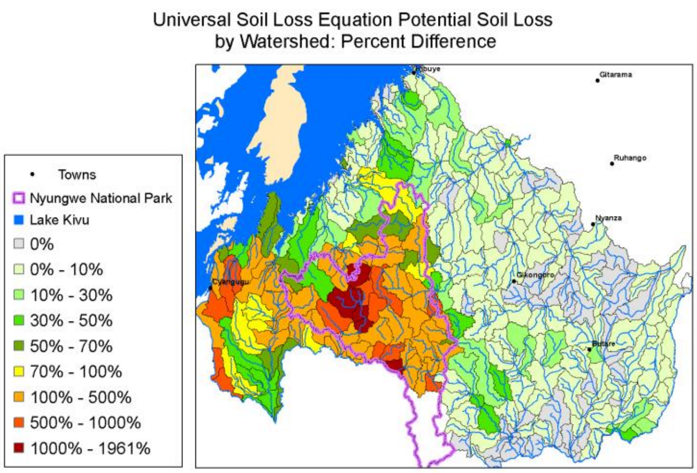


Figure 11. The percent difference in soil loss between baseline conditions and a scenario of 20% deforestation throughout the region. The boundaries of Nyungwe National Park are demarcated with purple lines.

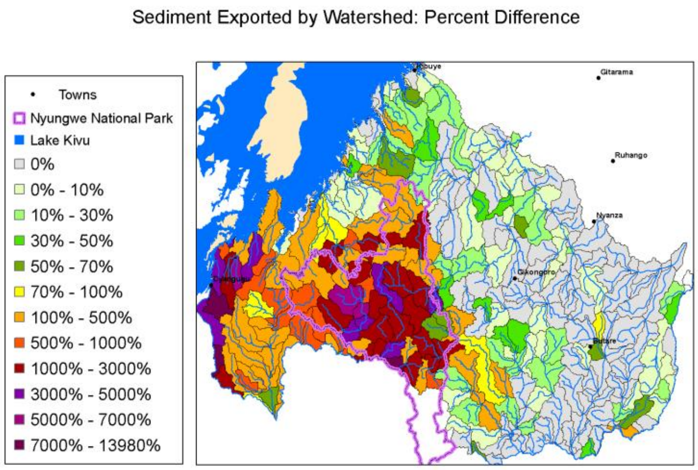


Figure 12. The percentage difference in sediment that would be exported per watershed under baseline conditions compared to a scenario of a 20% increase in deforestation throughout the region.

Scenarios were then created and run in InVEST to simulate how much sediment would be lost if 20% of the forest cover in the region was converted into cropland**.** Within NNP, if 20% of the forest cover is removed and converted into crop-land, very high rates of soil erosion result. If NNP is deforested, there is more than a 1000x increase in the amount of soil loss throughout much of the park (Figure 11). These results suggest that forests are playing an important part in holding and retaining sediment and can be used to assess how much sediment watersheds are exporting (Figure 12). The amount of soil lost and exported by a watershed in tons/hectare is an important metric for natural resource managers as it is strongly related to land-use conditions.

Summary of Results in Rwanda

Due to increases in temperature, the WASSI model results suggested that run-off (stream-flow) in Rwanda decreased over the last two decades, which means the amount of available water for the country could be decreasing. Nyungwe National Park (NNP) has relatively high water yield, which is about 30-40% of annual precipitation. The park currently has very low rates of soil erosion/sediment yields, but has a high potential for sediment loss due to high amounts of rainfall and steep slopes characterizing the area. In a scenario created in InVEST in which 20% of remaining forest was converted to cropland, huge increases in erosion and the soil exported from watersheds were observed. These potentially large increases in soil erosion and loss of sediment from the watersheds could decrease water quality substantially. Ground-data and monitoring programs are needed to estimate water balance and sediment loading, to improve the models' predictions, and reduce uncertainty. It will also be important in the next steps of the research to revisit the scenarios used and to include the Burundi part of the park in future analyses.

Ruaha River Valley, Tanzania

The same methods explained in detail for the Rwanda study were also applied in Tanzania and Zambia. The base-line conditions of temperature and precipitation in Tanzania using the globally available data did not reveal a clear trend in annual precipitation from 1960-2009 (Figure 13), but annual temperature does appear to have increased in the last 10 years (Figure 14), although, the significance of these trends have not yet been tested. WASSI simulations of run-off from 1960-2009 suggest that run-off has been decreasing inside and outside of Ruaha National Park in recent years (Figure 15).

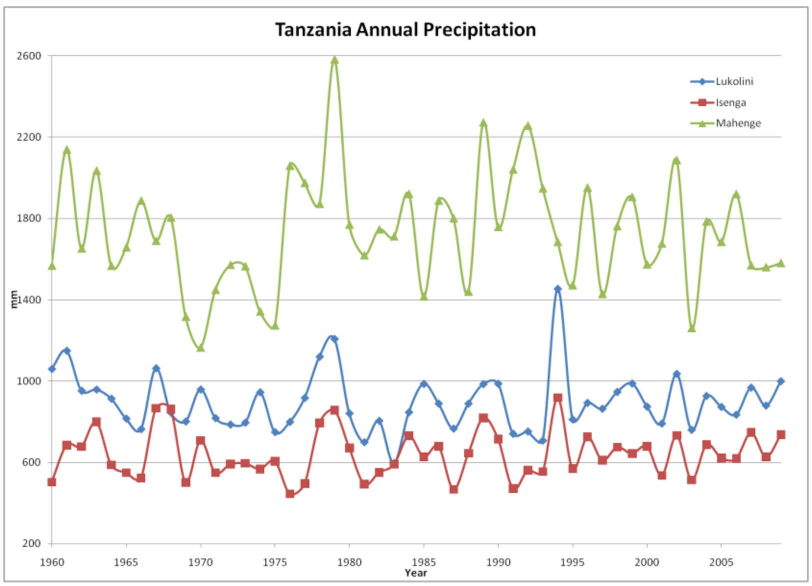


Figure 13. Annual precipitation in Tanzania from 1960-2009.

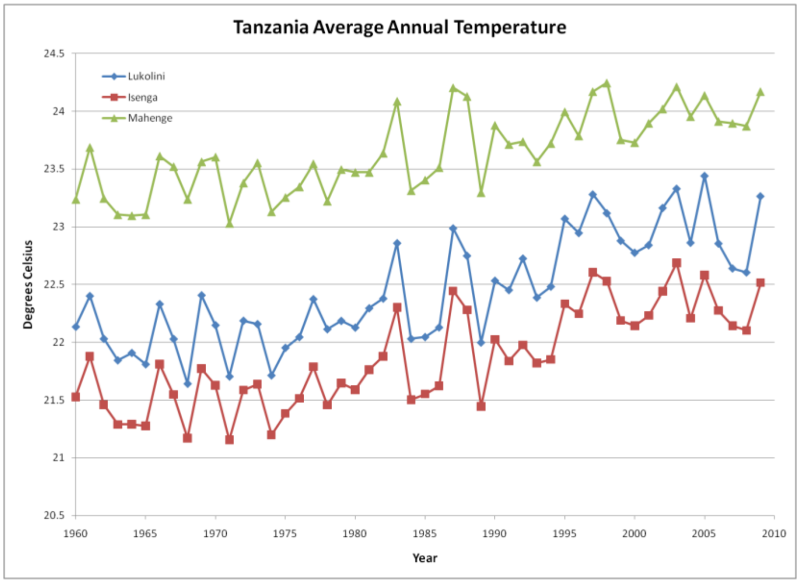


Figure 14. Annual average temperature in Tanzania from 1960-2009.

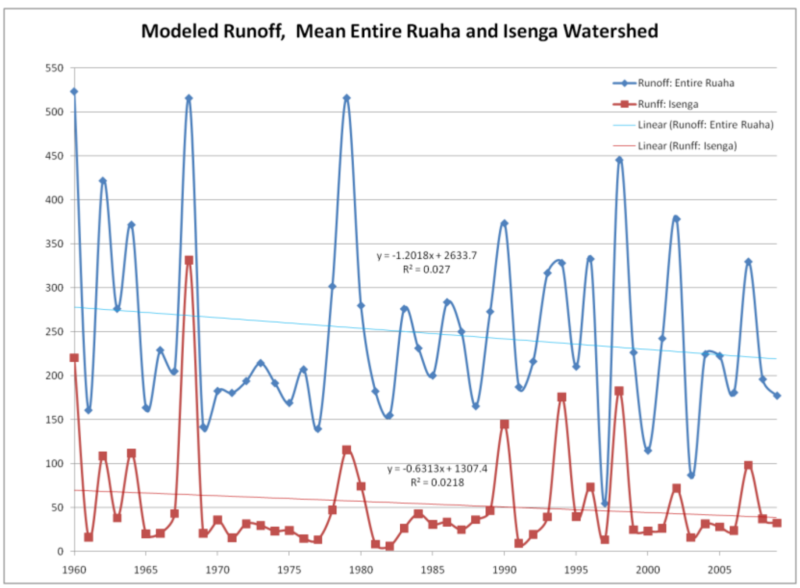
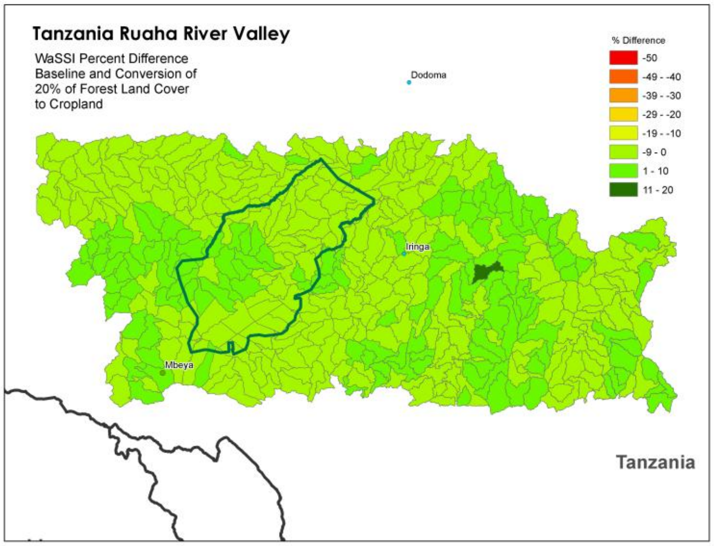
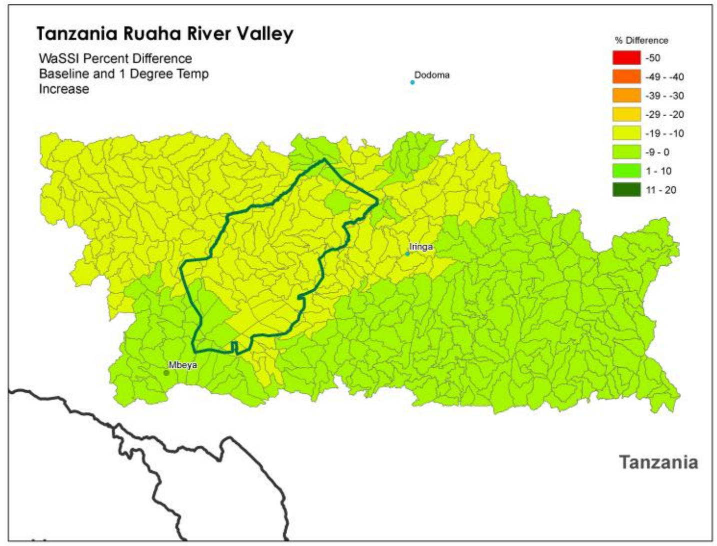


Figure 15. WASSI estimates of run-off in Tanzania from 1960-2009.

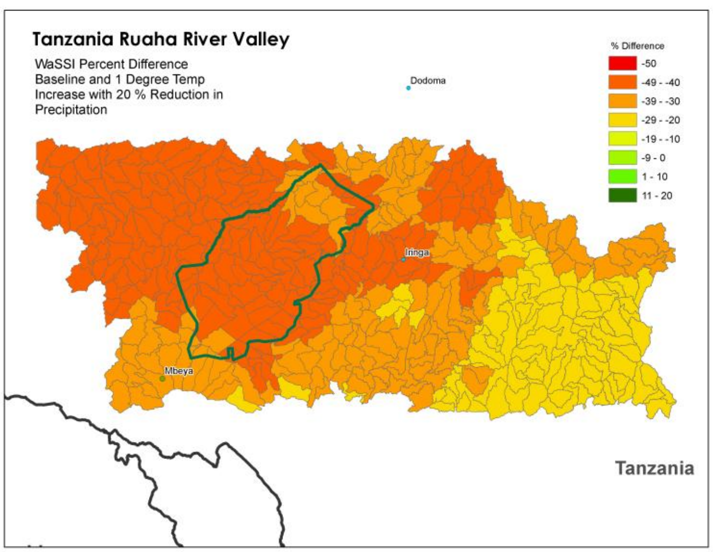
Similar to the simulations undertaken with WASSI in Rwanda, scenarios of 20% deforestation, a 1 degree celsius increase in temperature, and a 10% decrease in precipitation were created and run within WASSI for the Ruaha region. The results show that temperature and precipitation changes will most strongly affect run-off within Ruaha National Park. As can be seen in Figure 16, the changes in run-off as a result of temperature and precipitation changes will be distributed differentially throughout the park.





16a.

16b.

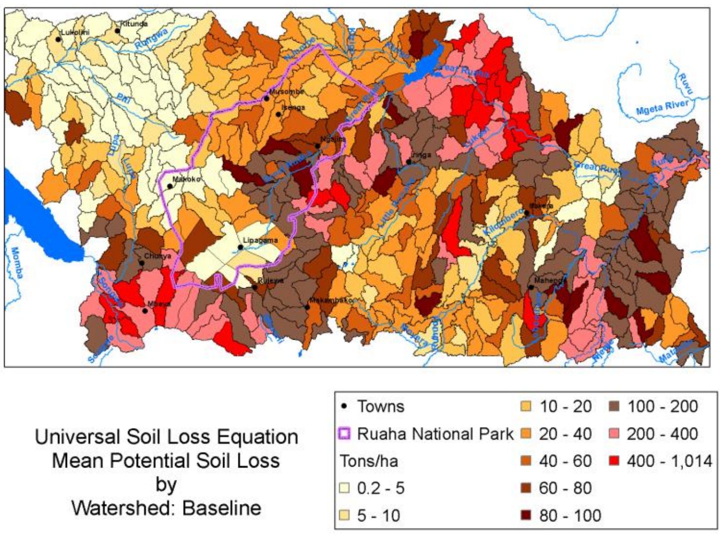


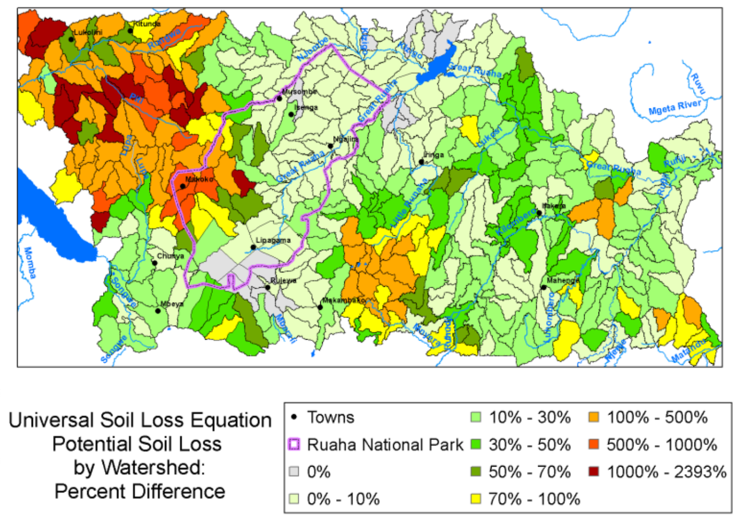
16c.

Figure 16a-c. The figure shows changes in run-off as a result of simulated changes in forest cover, temperature increase, and precipitation decreases in the Ruaha River Valley. Ruaha National Park is demarcated by black boundaries. 16a. The percent difference between the base-line conditions of run-off and run-off in a scenario of 20% deforestation. 16b. The percent difference between the base-line conditions of run-off and run-off in a scenario of 1 degree Celsius increase in temperature. 16c. The percent difference between the base-line

conditions of run-off and run-off in a scenario of a 1 degree Celsius increase in temperature and a 20% decrease in precipitation.

When the baseline amounts of soil loss (Figure 17) and sediment exported by watershed in Ruaha (Figure 18) were compared to the potential amounts of soil loss and sediment exported by watershed that might occur in a scenario of 20% deforestation in InVEST, there was a significant difference between the two sides of the park. The highest amount of soil loss and sediment exported occurred in the highlands above the park.





17a. **17b.**

Figure 17. 17a. Loss of sediment (tons/ha) under baseline conditions. 17b. The percent difference in the loss of sediment (tons/ha) as a result of 20% deforestation in the region.

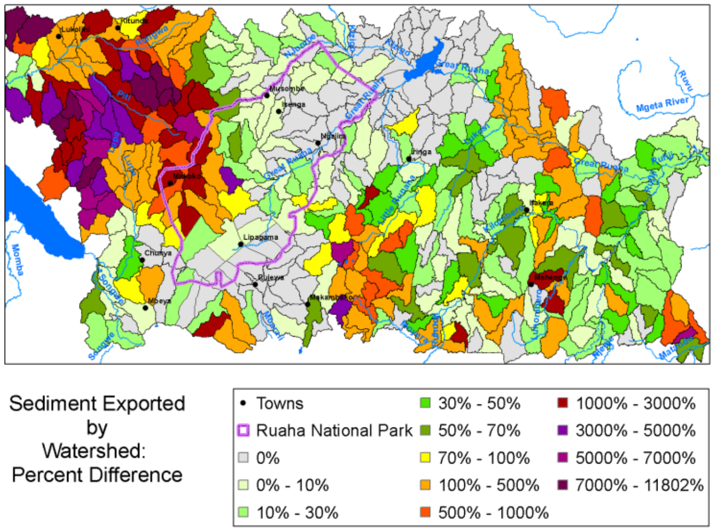


Figure 18. The percent difference in sediment exported by watersheds between baseline conditions and scenarios of deforestation.

Summary of Tanzania Results

In general, possible future climate change, such as increased temperature and reduced precipitation, could result in significant reductions in runoff in the Great Ruaha River region. Conversion of forest land to crop land could potentially reduce runoff in some areas and increase runoff in others, but any increase in runoff will not be sustained over time. In general, a conversion of forest land to agriculture land will increase the amount of sedimentation. Because land-use activities are currently managed inside the Ruaha National Park, the area of focus for any changes or policies in relation to land and watershed management should be in the watersheds located outside of the park, specifically within those watersheds whose sediment flows into the park. Within these watersheds, those with the highest potential for soil loss should be prioritized for the strongest land management restrictions. It was noted in the discussion by participants who are familiar with this part of Tanzania that some of the scenarios and model assumptions need to be revisited and the results, as presented currently, could be misleading.

Luangwa Valley, Zambia

As with all of the sites, data on historical trends in precipitation and temperature were assessed and used to develop simulations of run-off in WASSI (Figures 19-21). The Zambia case study is the only one of the three sites for which it was possible to validate the model predictions with ground-data. The validation exercise revealed that WASSI performed well at capturing measured trends of run-off, but in some cases overestimated the amount of run-off (Figure 22). Potential, future increases in air temperature and decreases in precipitation could decrease stream flow in the Luangwa Valley, based on WASSI simulations, but conversion of forest to crop land was predicted to have minimal impact on stream flow given current knowledge of leaf area change (Figure 23). However, the InVEST simulations revealed that deforestation would greatly increase both soil erosion and sedimentation (Figure 24-25).

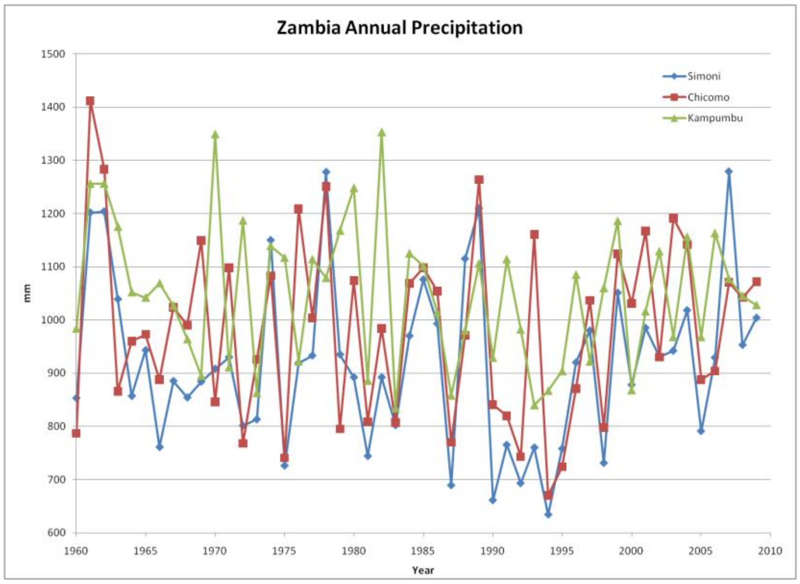


Figure 19. Zambia average annual precipitation from 1960-2009.

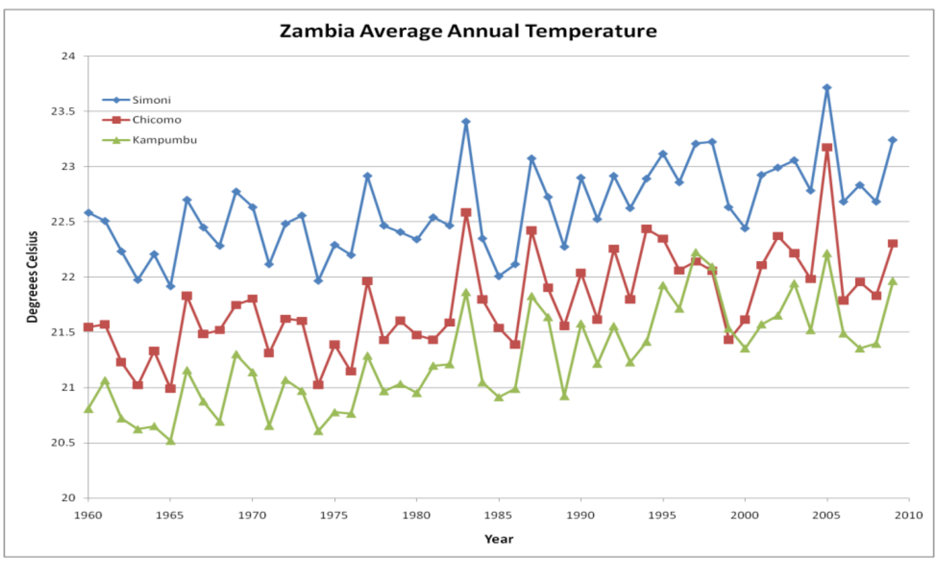


Figure 20. Zambia average annual temperature from 1960-2009.

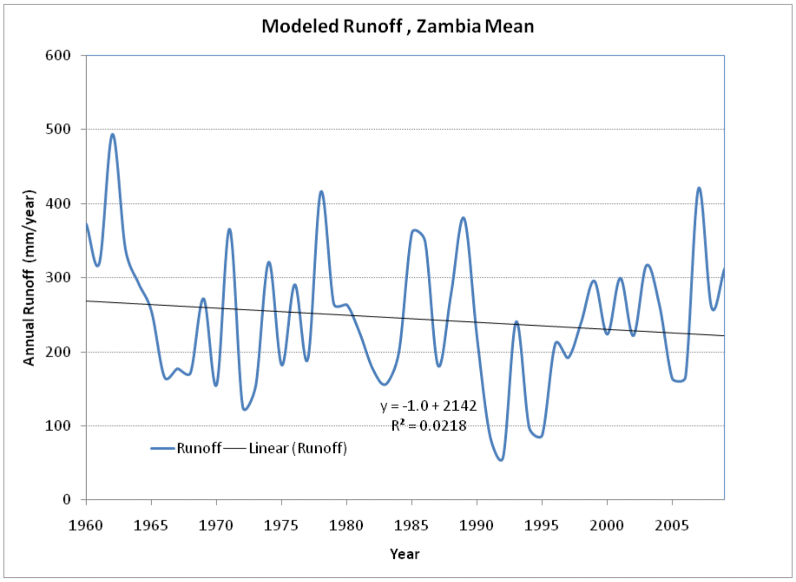


Figure 21. Run-off simulated in Zambia with WASSI from 1960-2009.

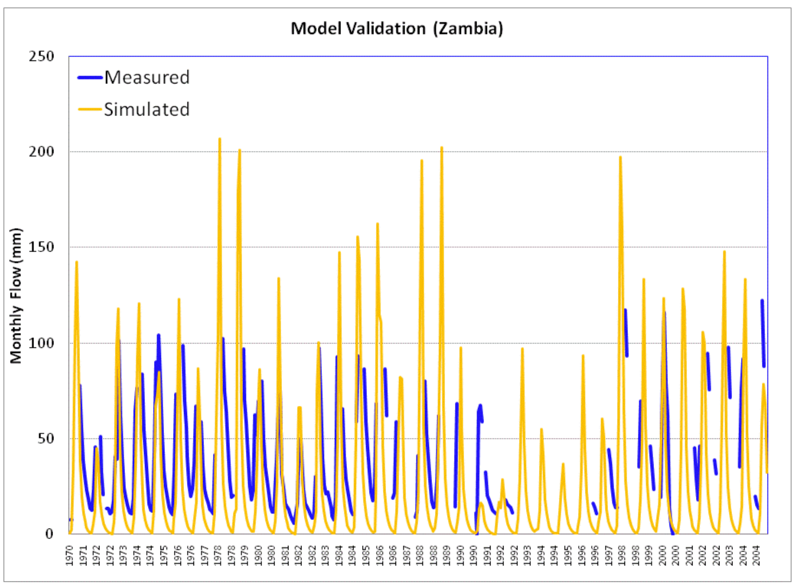
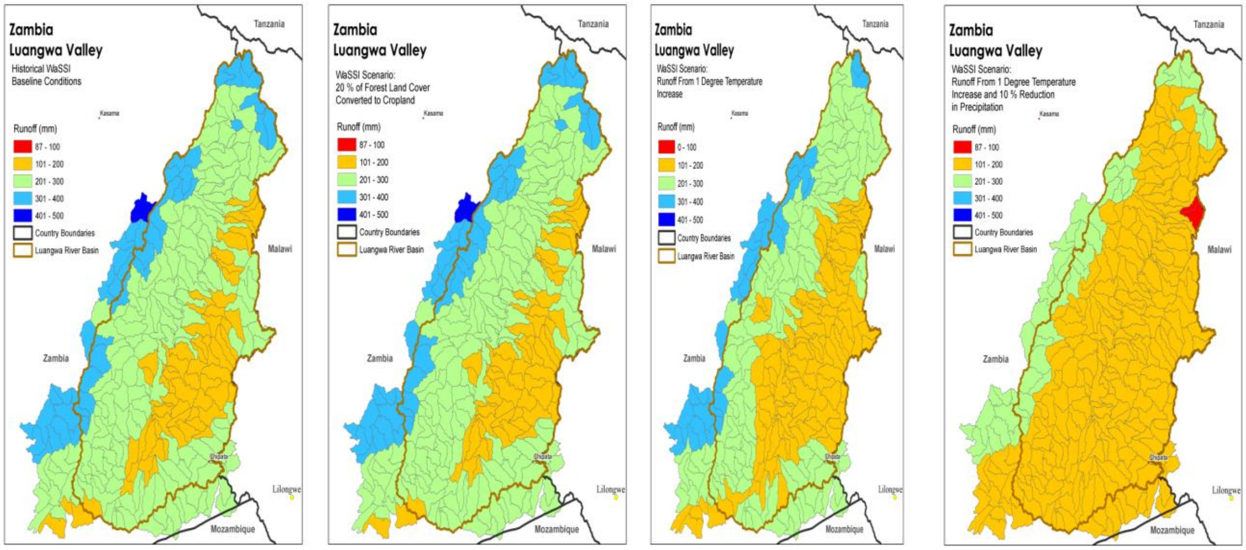
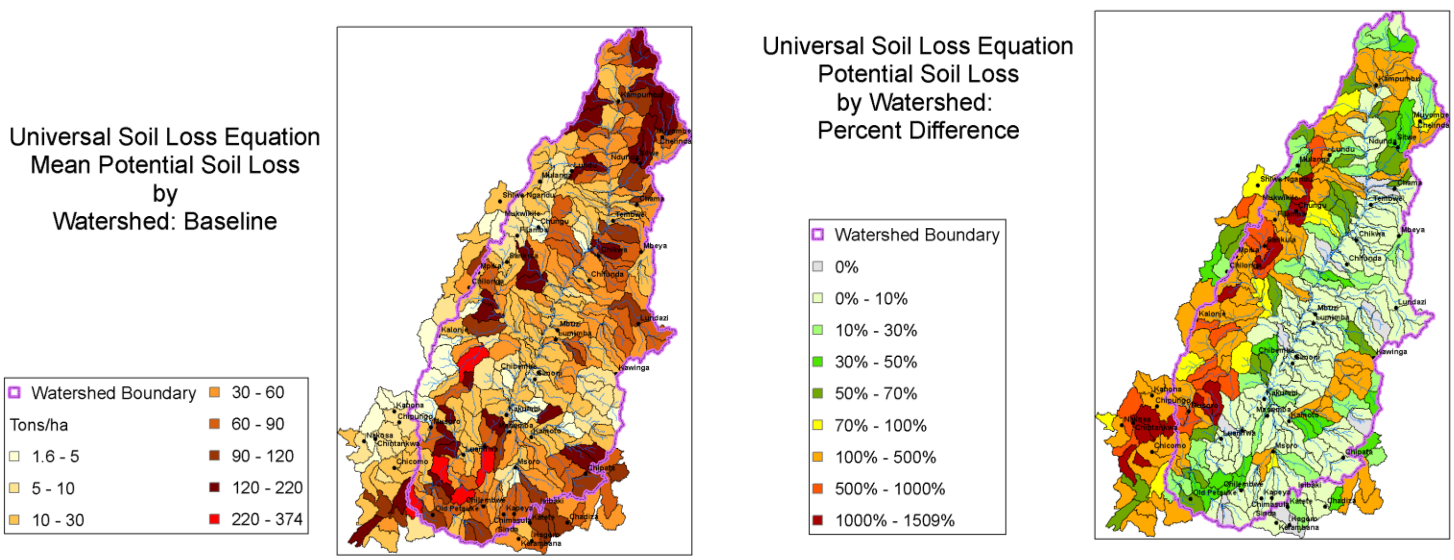


Figure 22. The results of the validation of WASSI estimates of average monthly run-off in Zambia with ground-collected data on monthly run-off from 1970-2004.



23a. 23b. 23c. 23d.

Figure 23. Run-off across the Luangwa Valley under baseline conditions (23a.), a scenario of 20% deforestation (23b), a scenario of 1 degree temperature increase (23c.) and a scenario of a 1 degree temperature increase and 10% reduction in precipitation (23d).



24a. 24b.

Figure 24. Soil loss under baseline conditions (24a.) and under a scenario of 20% loss of forest (24b.)

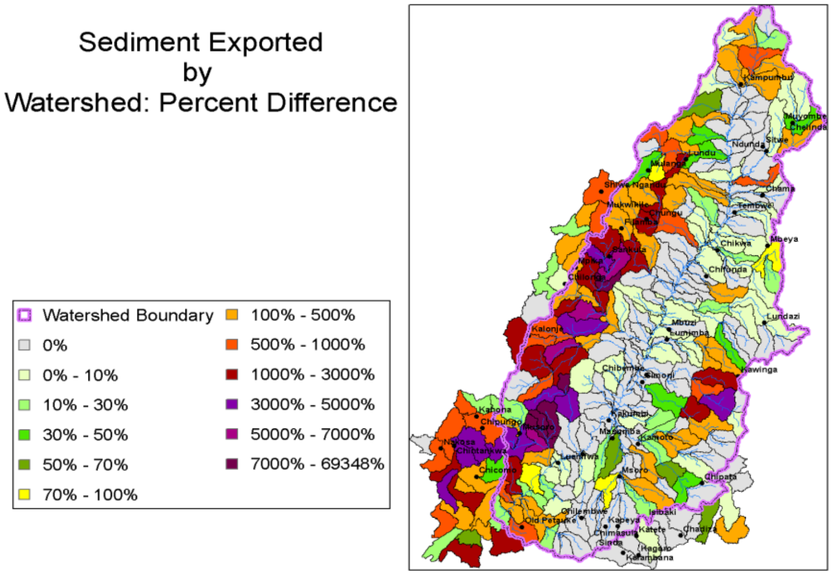


Figure 25. Percent difference in sediment exported by watershed between baseline conditions and scenarios of 20% deforestation in the Luangwa Valley.

Discussion Group Questions and Answers

At the end of the second day of the workshop, we formed several discussion groups to assess how the results presented throughout the meeting could be used and/or improved upon to better support decision making and water resource management throughout the region. The questions and group responses are included below.

Questions for Policy-Makers

1. How could results provided by the models used in the different case studies support policy-makers with decisions about watershed management?
    - The models can help with Environmental Impact Assessments and can help with water resource allocation.
2. What additional information do policy-makers need and want to make better decisions regarding watershed management and water resource use?
    - They need to know how much water is available in the country; WASSI provides information to answer to this.
    - We need to know how much water we need for each sector.
    - We need to know how to allocate water in an equitable manner- these models do not help as much with allocation.

3. What are the major barriers to developing and implementing effective watershed management and water resource policies?

- One of the barriers is not having enough information; scientists should assist with this.
- It is important to build the knowledge and capacity to understand and interpret the models.
- We need institutions that can help generate data and information on watersheds.
- We need to know what motivates competition between sectors:
    - We need information on costs of water use in different sectors.
    - One of the biggest challenges is supporting policy makers when faced with different decisions and different motivations that may influence the decisions they will make. To ensure they make informed decisions, information is needed on costs, public health consequences, and the impacts of different development choices.

Questions for Watershed Managers and Project Developers

1. How could the results provided by the models support watershed managers and project developers (e.g. developers of infrastructure projects for irrigation and hydropower) with implementation of integrated watershed management plans and/or water resource related projects?
    - Any of these models allow you to forecast rather than to be reactionary- as a manager it allows you to develop a strategy and not be opportunistic.
    - Without this information, they cannot look for new opportunities for support. So, it presents them with options for new funding opportunities and opportunities for educating people, engaging with people, and building constituencies for conservation.
    - The simulations they have developed with respect to climate change are quite helpful- these models allow you to develop clear predictions as to what would happen if deforestation or temperature increases. This allows us to prioritize our work.
    - These models help us to identify where we should be working and help us find the most sensitive area.
    - Many of the current maps for the Nile Basin do not include the forest for management/conservation because they assume that the Governments will conserve the forests, but this is not the case.
    - The results can help managers betters identify necessary interventions.
    - The models and graphs are helpful for working with policy makers.
    - As a manager, it can help refocus the management plan- this can help us adjust our management plan and our interventions.
    - Watershed management is quite expensive, but a map can allow us to focus scarce resources and prioritize where to work.
    - This kind of priority setting can also help with fundraising- if you can convince donors that you understand what is happening in an area (i.e. with climate change) and where you want to focus they might be more willing to support you.
    - These models allow you to focus your monitoring in the right areas.
    - The models help you to value certain areas, which can support the development of PES.
    - The models improve our ability to do sustainable land use planning.
    - The models only address issues of deforestation rather than forest degradation, which is also important to consider. (NOTE: The discussion revealed different land-use practices can be

integrated into the models used although not done in the analyses presented at the workshop).

2. What additional information do watershed managers and project developers need and want to make better decisions regarding implementation of integrated watershed management plans and infrastructure projects?
    - Socio-economic data- predictive evaluation of future socio-economic conditions
    - Population projections
    - The rate and extent of land use change
    - The ability to capture more natural resource management strategies within the model (i.e. deforestation to degradation). The model shows only going from forest to crop cover- it does not take into account degradation.
    - It does not tell you about the linkages among watersheds and this would be helpful.
    - Environmental profile of the watershed—so information on water allocation and demand; in the US WASSI has been used to look at demand/allocation
    - The cost of sedimentation- and if nothing is done, what would happen.
    - Water allocation/demand
    - Cost assessments (NOTE: we did not assess costs in this study, but InVEST has the capacity to do this).
3. What are the major barriers on the ground to implementing watershed management plans and providing supplies of sufficient water quality/quantity to people and needed by infrastructure projects?
    - Poverty and food security
    - Land management
    - Conflict (regional)
    - Population growth
    - Institutional frameworks
    - Issues related to land tenure
    - Lack of communication
    - When we are talking about Integrated Water Resource Management (IWRM), we are dealing with a lot of different people. If the institutional framework does not exist to work with these different groups, (IWRM) is difficult.
    - Conflicts of interest across ministries (food security, agriculture ministry, ministry of natural resources, political, or donor conflicts)
    - Lack of data – we don't have enough data to share
        i. Lack of harmony in data collection
        ii. Each country has their own laws and their own interests related to water resource management.
        iii. Lack of enforcement of current laws
    - Watershed management is not new, but there is a lack of understanding on what integrated watershed management means
    - Climate Change: We need to better understand climate change implications.

- Issue of scale- watersheds are much bigger than a National Park – scale of threats and opportunities
- Boundaries- political boundaries versus ecological boundaries: these are different
- Institutional boundaries- i..e different ministries charged with implementing IRWM
- Lack of capacity- human capacity (technical capacity), financial capacity

Questions for Scientists

1. What additional scientific information is needed to improve the accuracy and precision of the models to inform decision making associated with watershed management? What data should be prioritized if resources for data and monitoring are scarce?
    - Dynamic land cover information is needed, especially for savannahs and croplands
    - Soil data and geologic data are needed to better estimated base flow
    - Hydro-meteorological data for validation (Stream, sedimentation)
    - Socio-economic data

2. How much uncertainty in scientific results is acceptable and how much should be expected? How should decision-makers account for scientific uncertainty when developing policies or management plans?
    a. Participants thought that if you have certainty of 60% of greater that should be okay
    b. Estimate risk factors

Appendix 1: Participants at the Policy and Results Dissemination Meeting, September 13-14, 2011

First Name	Last Name	Organization
Marta	Alexande N'sumbo	OKACOM/Angola
Patrick Lola	Amani	OSFAC
Samuel	Ayebare	WCS/Uganda
Helene	Blanchard	WCS/Gabon
Chris	Brooks	Southern Africa Regional Environmental Program (SAREP)
Michel	Caubet	Sofreco Project Leader
Kyeyune	Charles	MINIRENA/Rwanda
Grace	Chitanda	Rufiji Basin Water Office/Tanzania
Erika	Cohen	USFS
James	Deutsch	WCS/NY
Matthew	Edwardsen	USFS
Jon	Erickson	Gund Institute for Ecological Economics, UVM
Bernard	Fosso	WCS/Cameroon
Umuhumuza	Gisele	REMA
Martin	Hega	WCS/Gabon
Umuganwa	Ines	REMA Protected Areas Biodiversity Project (PAB)
Carter	Ingram	WCS
Umuhoza	Jeanne d'Arc	MINIRENA/Rwanda
Mukurarinda	Juvenal	MINIRENA/Rwanda
Humphrey	K.	ERR Consulting
Vincent	Kabalisa	Deputy Director General for Water Resources/Rwanda
Julius	Kabubi	EAC
Aventino	Kasangaki	ARCOS
Ir. Claude	Kayitenkore	Directeur de l'Energie de l'EGL/Burundi
Francoise	Kayigamba	Nile Basin Initiative SAP
Wilfred	Kombe Ibey	DSFAC/GIRE
Innocent	Liengola	WCS/DRC
Steve	McNulty	USFS
Landing	Mane	OSFAC
Michel	Masozera	WCS/Rwanda
Bana	Mediatrice	WCS
Guy Alfred	Mouity	Ministry of Environment/Gabon
Aime	Mpambara	USAID
Raphael	Mpayana	REMA
Ragosian R.	Mtana	WCS/Tanzania
Antoine	Mudakiku	RDB-TXC
Grace	Mugoya	The New Times
Vincent	Muhitra	DG INECN/Burundi
Felix	Mulindahabi	WCS/Rwanda

J. Raymond	Munyamakombe	Conference Interpreter
Yolande	Munzimi	South Dakota State University/DRC
David	Mutekanga	GLOWS-RIWSP
Leon	Nabahungu	RAB/Rwanda
Simon	Nampindo	WCS/Uganda
Ndinomwaameni	Nashipili	Ministry of Agriculture, Water and Forestry, Namibia
Gaston	Ndayisaba	RNRA
Robert	Ndetiti	WWF/Kenya
Jean	Nduwamungu	NUR CGIS
Aaron	Nicholas	WCS/Rwanda
Antoine	Niragire	MINIRENA NBI/Rwanda
Janvier	Ntalindwa	SIDA
Godwell Elias	Ole Meing'ataki	Tanzania National Parks
Onkabetse	Rathari	Geological Survey Botswana
Louis	Rugerinyange	RDB/Nyungwe National Park
Eugene	Rurangwa	IGCP
Bernard	Rusana	Rwanda Agriculture Board (RAB)
Fidele	Ruzigandekwe	WCS/Rwanda
Leonardo	Saenz	Conservation International
Japhet	Seulu	Wcs/Zambia
Godfrey	Sengendo	Nile Basin Initiative Kagera River Basin Project
M. Manzi	Stella Malutina	REMA/PAB
Ge	Sun	USFS
Ngosa	Telesphire	RDB-TXC
Felin	Twagirashyaka	WCS/Congo
David	Wilkie	WCS/NY
Matt	Wingard	USFS

Appendix 2: Participants at the Training Workshop, September 15-16, 2012

First Name	Last Name	Organization
Marta	Alexande N'sumbo	OKACOM/Angola
Patrick Lola	Amani	OSFAC/DRC
Samuel	Ayebare	WCS/Uganda
Chris	Brooks	Southern Africa Regional Environmental Program (SAREP)
Kyeyune	Charles	MINIRENA/Rwanda
Erika	Cohen	USFS
Jon	Erikson	University of Vermont
Bernard	Fosso	WCS/Cameroon
Ndekezi	Francois-Xavier	MINIRENA/Rwanda
Gisele	Umuhumuza	REMA
Martin	Hega	WCS/Gabon
Blanchard	Helene	WCS/Gabon
Carter	Ingram	WCS/USA
Ndikubwimana	Innocent	RDB/Nympwe National Park (Rwanda)
Mukurarinda	Juvenal	MINIRENA/Rwanda
Julius	Kabubi	EAC
Aventino	Kasangaki	ARCOS
Wilfred	Kombe Ibey	DSFAC/GIRE
Innocent	Liengola	WCS/DRC
Landing	Mane	OSFAC
Michel	Masozera	WCS/Rwanda
Steve	McNulty	USFS
Bana	Mediatrice	WCS
Guy Alfred	Mouity	Ministry of Environment/Gabon
Ragosian R.	Mtana	WCS/Tanzania
Felix	Mulindahabi	WCS/Rwanda
Yolande	Munzimi	University of South Dakota
Leon	Nabahungu	RAB/Rwanda
Simon	Nampindo	WCS/Uganda
Ndinomwaameni	Nashipili	Ministry of Agriculture, Water and Forestry, Namibia
Robert	Ndetei	WWF
Jean	Nduwamungu	NUR-CGIS
Godwell Elias	Ole Meing'ataki	Tanzania National Parks
Onkabetse	Rathari	Geological Survey Botswana
Louis	Rugerinyange	RDB/Nyungwe National Park
Leonardo	Saenz	CI/US
Japhet	Seulu	WCS/Comaco
Ge	Sun	USFS

Felin	Twagirashyaka	WCS/Congo
David	Wilkie	WCS/NY
Matt	Wingard	USFS

Appendix 3. Meeting Agendas

Modeling and Managing Watersheds Workshop Agenda

September 13-14, 2011

Umubano Hotel, Boulevard de l'umuganda

Kigali, Rwanda

September 13, 2011

08:00 Registration

09:00 Welcome and Introductions, *Dr. Michel Masozera, Wildlife Conservation Society*

09:30 Keynote address by the Hon. Minister of Natural Resources, Rwanda

09:45 Introduction to the United States Forest Service (USFS) and the Wildlife Conservation Society (WCS) Collaborative Project on Watershed Modeling and Management in Rwanda, Zambia and Tanzania, *Mr. Matthew Edwardsen, United States Forest Service*

10:15 Watershed Management and Development in the Nile Equatorial Lakes Region: Perspectives and Challenges, *Mrs. Francoise Kayigamba, Nile Basin Initiative*

10:45 Coffee Break

11:15 Understanding the Use of Water Resources in the Nyabarongo Catchment, *Mr. Antoine Niragire, Nile Basin Initiative*

11:45 Watershed Management Challenges in Rwanda*, Mr. Leon Nabahungu, Senior Scientist, Rwanda Agricultural Board*

12:30 Lunch

14:00 Watershed Management Issues at Project Site in Zambia, *Japhet Seulu, Wildlife Conservation Society/Zambia*

14:30 Watershed Management Issues at Project Site in Tanzania, *Grace Chitanda, Rufij Water Basin; Ole Meingataki, Ruaha National Park; Rogasian Mtana, Wildlife Conservation Society/Tanzania*

15:00 How Project Models Have Been Applied to Address Watershed Management Challenges Around the World and Within Each Case Study Site, *Dr. Steve McNulty, United States Forest Service*

16:00 Coffee Break

16:30 Model Overview, *Dr. Ge Sun, United States Forest Service*

17:00 Adjourn

17:30 Reception at the Umubano Hotel

September 14, 2011

09:00 Welcome and Introduction to the Day, *Dr. Michel Masozera, Wildlife Conservation Society*

09:15 Kivu and Ruzizi River Basin Authority: A new initiative for integrated water resources management at a regional scale, *Ir Kayitenkore Claude, Directeur de l'Energie de l'EGL*

9:45 Results and Recommendations Rwanda Project, *United States Forest Service*

10:45 Morning Break

11:00 Results and Recommendations, Tanzania Project, *United States Forest Service*

11:45 Results and Recommendation, Zambia Project, *United States Forest Service*

12:30 Lunch

13:30 General Discussion on Project Results and Introduction to Working Groups

14:00 Break into Working Groups on the Use of Model Results to Address Watershed Management Challenges in the Region

15:00 Reports from Working Groups

15:30 Afternoon Break

15:45 Continue with Reports from Working Groups

16:30 Conclusions: Synthesis of the Meeting and Next Steps, *Dr. Michel Masozera, Wildlife Conservation Society*

15:30 Adjourn

Modeling and Managing Watersheds Workshop Agenda

September 15-16, 2011

Umubano Hotel, Boulevard de l'umuganda

Kigali, Rwanda

September 15, 2011

09:00 Welcome and Introductions, *Dr. Michel Masozera/WCS*

09:30 What is the Water Supply Stress Index-Carbon and Biodiversity (Wassi-CB) model?,

Ge Sun, USFS

- Objective
- Algorithms/Theory

10:15 Morning Break

10:45 What is Wassi-CB, Continued?, *Dr. Ge Sun and Mr. Matthew Wingard, USFS*

- Databases
- Model Application

11:30 Install Wassi on Computers and Walk through WaSSI model on computers
Dr. Ge Sun, Ms. Erika Cohen, and Mr. Matthew Wingard, USFS

12:00 Lunch

13:00 Wassi Exercise and Break Into Groups, *Dr. Steve McNulty, Dr. Ge Sun and Ms. Erika Cohen, USFS*

15:30 Afternoon Break

16:00 Finish Wassi Exercises/ Start Group Presentations

17:30 Wrap-Up and Adjourn for Day

September 16, 2011

09:00 Review of Wednesday, *Dr. Steve McNulty, Dr. Ge Sun and Ms. Erika Cohen, USFS*

10:00 Assessing Soil Erosion with the Universal Soil Loss Equation and the use of the Integrated Valuation of Ecosystem Services and Tradeoffs (InVest) Model, *Dr. Steve McNulty, and Ms. Erika Cohen, USFS*

11:00 Morning Break

11:15 Assessing Soil Erosion with the Universal Soil Loss Equation and the use of the Integrated Valuation of Ecosystem Services and Tradeoffs (InVest) Model *(continued)*, *Dr. Steve McNulty, and Ms. Erika Cohen, USFS*

12:00 Lunch

13:00 What is Artificial Intelligence for Ecosystem Services (ARIES)?, *Dr. Jon Erikson, University of Vermont*

15:00 Afternoon Coffee

15:30 Wrap Up Discussion and Synthesis

17:00 Adjourn

Appendix 4. Glossary of Key Terms

Afforestation: The establishment of a forest or stand of trees in an area where there was no forest.

Acutal evapotranspiration (AET): A measure of the amount of water actually evapotranspirated from the plants and soil system and takes into account the conditions of the plant/soil system.

Carbon sequestration(terrestrial): The process through which carbon dioxide from the atmosphere is absorbed by trees, plants and crops through photosynthesis, and stored as carbon in biomass(tree trunks, branches, foliage and roots) and soils.

Cover management factor (C factor): The ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow.

Crop rotation: A system of farming in which a succession of different crops are planted on the same land area, as opposed to growing the same crop time and time.

Deforestation: The removal of a forest or stand of trees where the land is thereafter converted to a non-forest use.

Ecosystem : A biological environment consisting of all the organisms living in a particular area, as well as all the nonliving (abiotic), physical components of the environment with which the organisms interact, such as air, soil, water and sunlight.

Ecosystem Services: The fundamental life-support services upon which human life and civilization depend, which can be direct or indirect. Broad categories of ecosystem services include: regulating (climate control, flood regulation, water filtration); provisioning (food, medicine, fibers, minerals); cultural (science, spiritual, ceremonial, recreation, aesthetic); and supporting (nutrient cycling, photosynthesis, soil formation). The services and goods an ecosystem provides are often undervalued and many of them are without market value.

Ecosystem Respiration (Re): Ecosystem respiration is the sum of all respiration occurring by the living organisms in a specific ecosystem. Ecosystem respiration is typically measured in the natural environment. Ecosystem respiration is the production portion of carbon dioxide in an ecosystem's carbon flux, while photosynthesis typically accounts for the majority of the ecosystem's carbon consumption. Measurements of Re can be used to estimate Gross Ecosystem Productivity (GEP); GEP= Re-NEE.

Erosion: The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep.

Evaporation (E): The physical process by which a liquid is transformed to a gaseous state.

Evapotranspiration (ET): The combination of water transpired from vegetation and evaporated from the soil and plant surfaces.

Gross primary production (GPP): the rate at which an ecosystem's producers capture and store a given amount of chemical energy as biomass in a given length of time. Some fraction of this fixed energy is used by primary producers for cellular respiration and maintenance of existing tissues (i.e., "growth respiration" and "maintenance respiration"). The remaining fixed energy (i.e., mass of photosynthate) is referred to as net primary production (NPP). NPP = GPP - respiration [by plants].

Gross Ecosystem Production (GEP): used inter-changeably with GPP, most by the eddy carbon flux measurement community.

Net Ecosystem Exchange (NEE): Net carbon uptake by an ecosystem. By convention, an ecosystem is a carbon sink when NEE is negative, otherwise it is a carbon source. NEE can be measured by eddy flux equipments and is used to estimate gross ecosystem productivity (GEP).

Groundwater: All water that exists beneath the land surface, but more commonly applied to water in fully saturated soils and geologic formations. Groundwater and surface interacts to form one single water resources.

Groundwater flow: Flow of water that is derived from groundwater system.

Leaf area index (LAI): The ratio of total upper leaf surface of vegetation divided by surface area of land on which the vegetation grows. LAI is used to predict ET, primary productivity and crop growth.

Potential evapotranspiration (PET): Water loss through ET from soil and plant surfaces when water is not limiting. PET is affected by atmospheric conditions.

Permeability: The specific soil property designating the rate at which gases and liquids can flow through the soil or porous media.

Rainfall erosivity (R): A measure of rainfall's ability to detach and transport soil particles.

Reforestation: The restocking of existing forests and woodlands which have been depleted, an effect of deforestation.

Runoff: The portion of precipitation, snow melt, or irrigation that flows over and through the soil, eventually making its way to surface water supplies. This term can be used as having the same meaning of streamflow

Sediment load: Amount of sediment carried by running water or wind.

Sedimentation: Deposition of waterborne or wind borne particles resulting from a decrease in transport capacity.

Slope length (LS): The horizontal distance from the origin of overland flow to the point where either (1) the slope gradient decreases enough that deposition begins or (2) runoff becomes concentrated in a defined channel.

Slope length factor (L): The ratio of soil loss from the field slope length to soil loss from a 72.6-ft length under identical conditions.

Slope steepness factor (S): The ratio of soil loss from the field slope gradient to soil loss from a 9% slope under otherwise identical conditions.

Soil erodibility (K): A measure of the soil's susceptibility to erosional processes.

Soil erosion: Detachment and movement of soil from the land surface by wind or water. [2]

Soil structure: The combination or arrangement of primary soil particles into secondary particles, units, or peds that make up the soil mass. The secondary units maybe, but usually are not, arranged in the profile in such a manner as to give a distinctive characteristic pattern. The principal types of soil structure are platy, prismatic, columnar, blocky, and granular.

Soil texture: Classification of soil by the relative proportions of sand, silt, and clay present in the soil.

Support practice factor (P): The ratio of soil loss with a support practice like contouring, stripcropping, or terracing to soil loss with straight-row farming up and down the slope.

Surface runoff: Precipitation, snow melt, or irrigation in excess of what can infiltrate or be stored in small surface depressions.

Surface water: Water that is on the earth surface, such as in a stream, river, lake, or reservoir.

Universal soil loss equation (USLE): An equation that enables planners to predict the average rate of soil erosion for each of various alternative combinations of cropping systems, management techniques, and erosion control practices on any particular site.

Watershed: Land area that contributes runoff (drains) to a given point in a stream of river. Synonymous with catchment and drainage or river basin.

Watershed management: the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within a watershed boundary. Understanding watershed hydrology is the key toward integrated watershed management.