CGIAR RESEARCH PROGRAM ON Water, Land and Ecosystems
LED BY: IWMI International Water Management Institute

PROCEEDINGS OF THE WORKSHOP TO ESTABLISH GUIDELINES FOR USING SWAT TO ASSESS ECOSYSTEM SERVICES

INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE CAMPUS, ADDIS ABABA, ETHIOPIA, 15-17 OCTOBER 2014

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IN PARTNERSHIP WITH:
Bioversity International · CGIAR Challenge Program on WATER & FOOD · CIAT · CIP · FAO · ICARDA · ICRISAT · IITA · IFPRI · ILRI · World Agroforestry Centre · WorldFish

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Executive Summary

In early 2014 as part of the **CGIAR Research Program on Water, Land and Ecosystems' (WLE) Managing Resource Variability and Competing Use (MRV) research theme**, a decision was made to establish a SWAT (Soil and Water Assessment Tool) Community of Practice. The MRV research theme seeks to integrate future water needs scenarios in key sectors and the environment to improve water security through:

- Managing water resources' variability and re-thinking storage in basins
- Resource allocation and benefit sharing
- Water and energy for food
- Water data and accounting in basins

In addition, within WLE, there are three cross-cutting themes on 1) Gender, Poverty and Institutions and 2) Ecosystem Services and Resilience 3) Decision Analysis and Information Systems. These themes seek to support more gender equitable access to water, land and ecosystem services and establish more holistic ecosystem based approaches to management, including the development of methods and measurements for assessing ecosystem service status and delivery.

Across many of the CGIAR Research Programs and projects, SWAT has become a common tool that researchers implement to assess alternative land use management scenarios at multiple spatial and temporal scales and under expected potential future climates. Adhering to the old modeling adage put forth by mathematician George Edward Box that "*All models are wrong, but some are useful*", several researchers across CGIAR centers began discussing the need to insure SWAT model use was being undertaken with scientific rigor, that researchers new to the SWAT model were provided with adequate training and support, and that there was a way for researchers to meet and communicate with one another about the challenges and opportunities faced when working with the model in data scarce regions. An exploration was then undertaken to determine if there was enough interest and need across the CGIAR to establish a Community of Practice dedicated to these purposes. The response was overwhelmingly positive across all regions and results from the survey clearly indicated that Ecosystem Services assessments were one of the primary reasons that researchers were using SWAT.

To establish guidelines and best practices for using SWAT to assess ecosystem services, WLE, led by IWMI, organized a three-day workshop for advanced members of the SWAT Community of Practice to meet on the ILRI Campus in Addis Ababa, Ethiopia. Twelve members of the Community of Practice, representing IWMI, CIAT, ICARDA, IFPRI, and ICRISAT attended the workshop. During the workshop, participants heard about efforts under way on projects throughout regions where the CGIAR centers work (sub-Saharan Africa, Latin America, Central Asia, Middle East and Northern Africa, India, South Asia, Southeast Asia, as well Global Applications). Participants then engaged in activities to help tease out the first set of critical ecosystem services that will be discussed in guidelines for using SWAT to assess ecosystem services, and finally they began writing those guidelines using the collaborative CGxChange work environment.

Due to the success of the 2014 workshop, participants will continue with WLE support to engage in building the CGIAR SWAT Community of Practice, introducing an initial set of guidelines for using SWAT to assess Ecosystem Services during 2015.

The workshop organizers and participants would like to thank the CGIAR Research Program on Water, Land and Ecosystems for sponsoring the workshop and the development of the Community of Practice; Co-leaders of the River Basins SRP, Vladimir Smakhtin, Principal Researcher – Theme Leader – Water Availability, Risk & Resilience, IWMI and Claudia Ringler, Senior Fellow, IFPRI for their suggestions and support of Community of Practice development; Simon Langan, Principal Researcher – Agricultural Water Management and Head of Office, International Water Management Institute (IWMI), Addis Ababa, Ethiopia; Nigist Wagaye, Programme Management Officer, IWMI, Addis Ababa, Ethiopia; and Rahel Mesganaw, Senior Administrative Assistant, for logistical support in Addis Ababa; Raghavan Srinivasan – SWAT Developer and Professor, Texas A&M University who assisted in facilitating the workshop; Martin Volk – Head of Department of Computational Landscape Ecology, Helmholtz Centre for Environmental Research – UFZ for providing slides in his absence; Noa Gutterman – Fulbright Scholar with IWMI during 2014 – 2015, for graciously taking excellent notes during the meeting; Dessalegn Tadesse for taking our group photos; and Patrick Baker, Independent Researcher in Ecology; Valentine Gandhi, Researcher – Social Sciences, IWMI; Kai Wegerich, Senior Researcher – Water Policy and Institutions; Abby Waldorf –

Communications Officer, WLE; and Daniel van Rooijen, for ensuring that viewpoints about habitat and people were included in the Gallery Walk and general discussions.

Tracy Baker
Researcher – Hydrology and Hydrological Modelling (IWMI)
SWAT Community of Practice Facilitator (WLE)

Organizers

IWMI

The International Water Management Institute (IWMI) is an international, non-profit research organization dedicated to improving the management of land and water resources for food, livelihoods and the environment. IWMI is a member of CGIAR, an international consortium of agricultural research centers. IWMI's mission is to improve the management of land and water resources for food, livelihoods and the environment. IWMI's vision, as reflected in the Institute's Strategic Plan, is water for a food secure world. IWMI targets land and water management challenges faced by poor communities in the developing world. Research for development (R4D) is the core activity of IWMI. The Institute's research agenda is organized around four priority themes: Water Availability and Access; Productive Water Use; Water Quality, Health and Environment; and Water and Society. IWMI works through collaborative research with many partners in the North and South and targets policymakers, development agencies, individual farmers and private sector organizations. For more information, please visit http://www.iwmi.cgiar.org/index.aspx

WLE

The CGIAR Research Program on Water, Land and Ecosystems (WLE) is an ambitious twelve-year program that brings together innovative thinking on agriculture, natural resource management and poverty alleviation to deliver effective solutions for food security and environmental protection. Unmatched in CGIAR, both in terms of its scope and range of partners, the Program brings together specialists in CGIAR subject matter to solve pressing problems in specific focal regions. The vision of WLE is "a world in which agriculture thrives within vibrant ecosystems, and where communities have higher incomes, improved food security and the ability to continually improve their lives." For more information, please visit http://wle.cgiar.org/

Overview

This report provides an overview of the development and planning for a SWAT Community of Practice within the CGIAR as well as summaries of presentations and discussions held during the *Workshop to Establish Guidelines for Using SWAT to Assess Ecosystem Services*.

Part 1 describes the reasoning and process undertaken for establishing the SWAT Community of Practice in early 2014. Part 2 summarizes the workshop held at the ILRI campus in Addis Ababa. Appendices are included that detail the survey and subsequent meeting agenda as well as participants.

Part 1: Establishing the Community of Practice

A Community of Practice is a theory of learning or social participation whereby people, often professionals, come together to share experiences they have in a common trade or craft. People within the community do not just have an interest in, but active practitioners and experts in craft or trade of focus. Members of the community share their knowledge with one another and provide support for one another in supporting best practices. Perhaps most importantly, Communities of Practice are participatory in nature, allowing members to share their experiences in a commonly understood language natural to its members and resulting therefore in more of a storytelling environment.

With this in mind, goals in establishing and fostering a Community of Practice within the CGIAR system around the SWAT model are:

1. To provide an environment, both in person and virtually, for CGIAR researchers working with SWAT to discuss challenges, propose solutions, and establish best practices.
2. To identify needs for model development to improve SWAT model usage in the developing world.
3. To explore opportunities for collaborative research activities using SWAT among CGIAR Centers and Programs as well as with external organizations.

To meet these goals, a survey was carried out in February, 2014 that was sent to researchers at all 15 CGIAR Centers worldwide (Appendix A). Sixty-three people representing eleven centers (IWMI [17], CIAT [8], CIMMYT [8], ICARDA [8], ICRAF [7], ILRI [5], ICRISAT [4], IITA [2], CIFOR [1], IFPRI [1], and IRRI [1]) responded to the survey, though only 50% of these respondents were current SWAT users. User experience in years ranged from 1 – 12. Figures 1 – 5 illustrate responses by users to questions that helped define the focus of the Community of Practice in its first year. It was clear that users in Latin [3] and North America [1] are quite isolated from those in Africa and Middle East [26] and Asia [19] and so efforts put specifically put forth to bring in those members to more fully integrate our community with a diversity of experiences and ideas on using the model.

Respondents who had no SWAT training and were just getting started with the model were invited to attend a training event sponsored by USAID's Feed the Future Innovation Lab for Small-Scale Irrigation also held at the ILRI campus in Addis Ababa, Ethiopia in June 2014. Six Community of Practice members attended this training event.

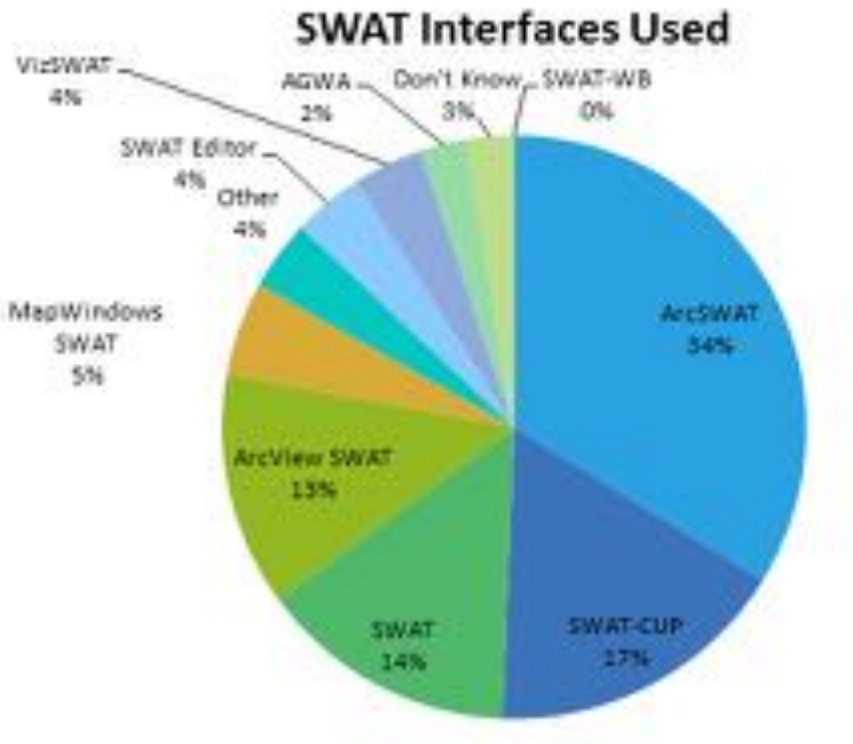

Figure 1: Please indicate which SWAT interface(s) you have used, are currently using, or are planning to use.

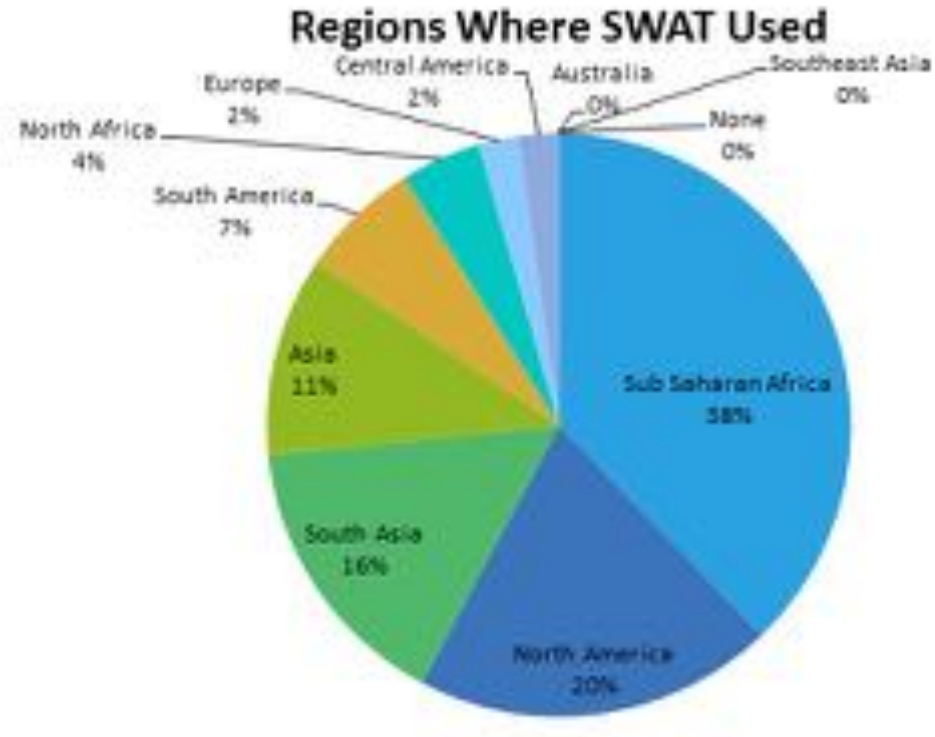

Figure 2: Which general regions have you worked in with the SWAT model?

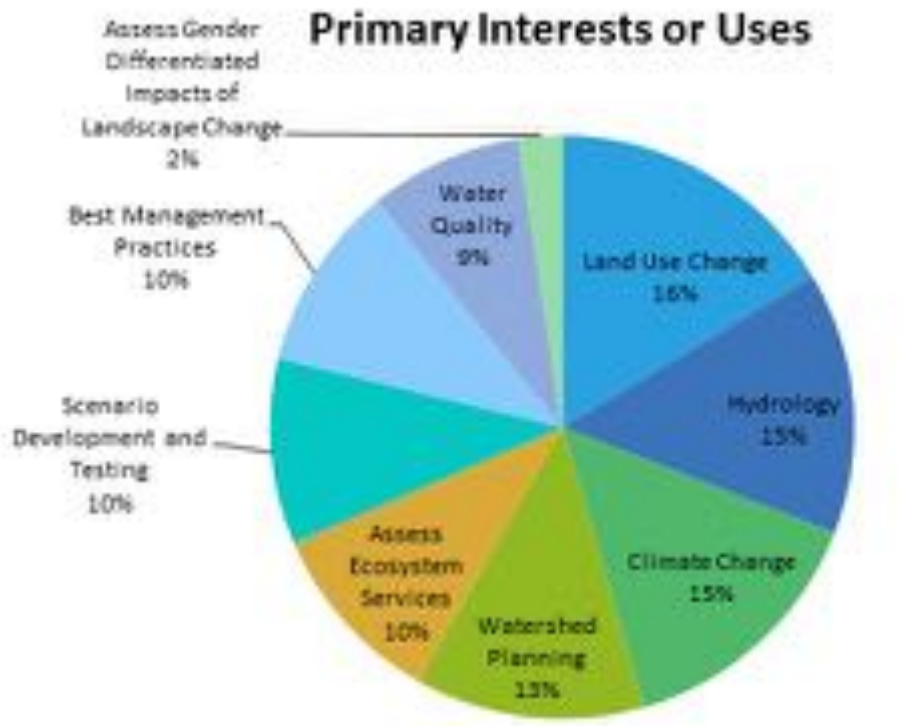

Figure 3: What are your primary interests in SWAT in your projects?

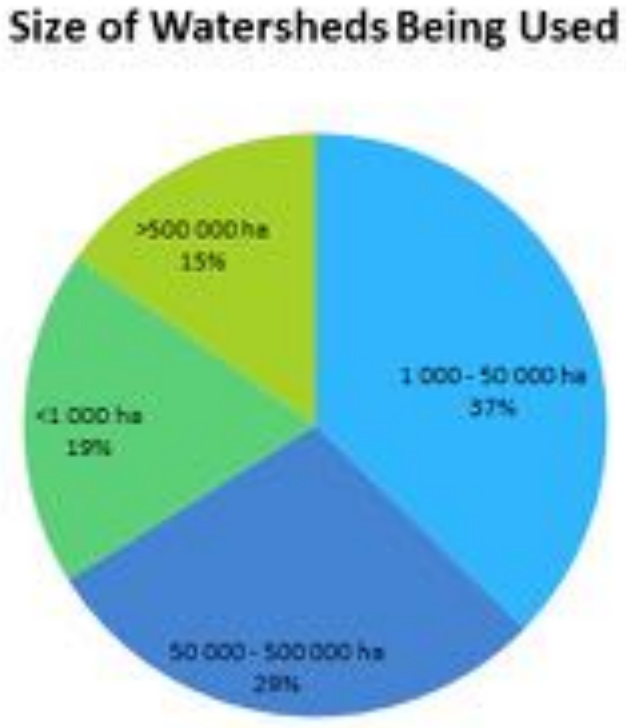

Figure 4: What size watersheds or basins do you typically work in with SWAT?

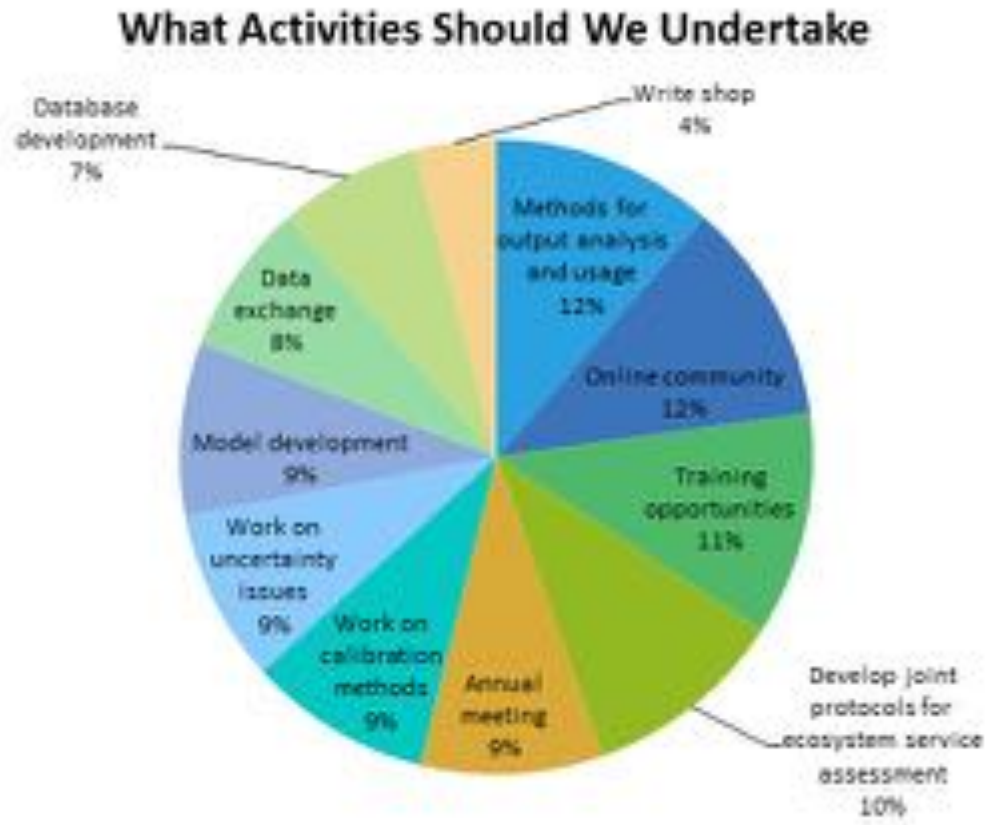

Figure 5: Which of the following types of activities would you be interested in seeing from a CG-wide SWAT Community of Practice?

Part 2: Workshop Proceedings

Day 1: Establishing work contexts

The first day of the workshop was intended to formally introduce colleagues to one another and discuss the role of Communities of Practice as well as allow participants to give informal presentations about their work with SWAT or Ecosystem Services.

Session 1: Welcome and Opening

Simon Langan, Nile Basin Focal Region Leader, opened the meeting, welcoming the guests and discussing WLE Focal Regions. He stressed that there needs to be a balance between model development and model use with a focus on how to bring economics into the spectrum and water related ecosystem services. In 2016, all programs will come to a conclusion. He stressed that SWAT is seen as a great way that information about ecosystems can be communicated.

Tracy Baker, IWMI Researcher and SWAT Community of Practice facilitator, first discussed Communities of Practice generally and ideas for developing the CGIAR SWAT Community of Practice. She discussed the primary uses and interests and activities that researchers indicated they would be most interested in undertaking according to the earlier survey.

She further elaborated on plans for the next Community of Practice meeting, stressing that the members should try to meet annually. Options presented to the group were to hold the next meeting at either the International Association of Hydrological Sciences meeting in Prague (22 June – 2 July, 2015) of the International SWAT Conference in Sardinia (22 June – 26 June, 2015). The majority of community members expressed that they prefer the International SWAT Conference, as several were already planning to present research there. The group also concluded that they would open the meeting to the larger CGIAR SWAT Community.

Presentation: Ecosystem Services: Terminology and Definitions
By: Tracy Baker, IWMI Researcher and SWAT Community of Practice facilitator

Summary

- Let's all get on the same page about the definitions we will use for this workshop when discussing ecosystem services
- Ecosystem Services are people focused and people defined for the benefit of humanity
- We will use four categories of ecosystem services: Provisioning [food, water, fuel, wood], Regulating [climate, flood, disease, water purification], Cultural [aesthetic, spiritual, educational, recreational], and Supporting [soil formation, nutrient cycling, primary production]
- A vitally important aspect of Ecosystem Services is that they represent a direct link to people
    - How will we demonstrate this with SWAT? This is what our group must answer.
- WLE has a new framework for Ecosystem Service and Resilience
    - People: Meeting the needs of people is fundamental
    - Ecosystem services and associated benefits: People and nature are fundamentally linked
    - Ecosystems: Cross scale and cross level interaction can be managed to positively impact development outcomes
    - Governance decisions: Governance mechanisms are vital tools for achieving equitable access to and provision of ecosystem services
    - Influencing factors: Building resilience is about enhancing capacities to sustainably develop in an uncertain world
- For the final guidelines that we prepare, we need to think in terms of WLE Typology of Ecosystem Services: Provisioning, Regulating, Habitat, and Cultural
- Sometimes ecosystems and ecosystem services are in conflict. Example: floods can be good for a flood dependent ecosystem, but bad for delivering certain services to human beings and so there are always tradeoffs.

Presentation: Ecosystem Services and River Basin Models
By: Martin Volk (presented by Raghavan Srinivasan)

Summary: More work is needed on ecosystem services modeling involving dynamic feedbacks ad that include the important socio-political influences. There are gaps to be filled in Ecosystem services modelling.

- Ecosystem services are benefits to humans
- We use modelling to quantify various feedbacks and interactions among ecosystem function and services
    - Must encompass the social, economics, and ecological
- Work needs to support the development of policies and practices
- Deficits in current modelling of ecosystem services
    - Diverse heterogeneous modelling systems are sued and range from simple to complex with no real integration
    - Offsite effects aren't considered
    - Stakeholders are general not actively involved
    - Feedbacks and tradeoffs aren't considered or quantified
        - Often proxy variables are used
    - Scenario analysis is separate from explorative modelling that shows landscape potential to provide several simultaneous ecosystem services
        - Example: Freshwater ecosystem services tools: SWAT, VIC model, InVEST, ARIES (no single model satisfies everyone's needs)
    - Exploratory modeling in dynamic systems – tradeoffs
        - Landscapes fulfill different functions and provides different services that have to be provided at the same time, for example assessing whether it is possible to provide the same agricultural yield but protect more water provisions for biodiversity
    - Tendency is look only at local benefits rather than macro scale

Presentation: Ecosystem services of Tigris River
By: Raghavan Srinivasan, Texas A&M University, Professor, Ecosystem Sciences and Management and Biological and Agricultural Engineering, SWAT Developer

Summary: The world's largest marshland and the Middle East's largest river basin are under severe threat from human intervention and development in an area where there is a great deal of political turmoil. Developments planned with further exacerbate these issues in the region bringing further instability. This presentation focused on complex geopolitical challenges in water management.

- Hawizeh Marshland is saltier than sea and feeds a large community of people in Iraq and Iran; it is largest in the world (4000 km^2); largest river basin in Middle East
    - Basra is just below the marsh
- Reported just on quantity, not quality of the river basin
- Most flow comes from Euphrates in Turkey (21% of area but 98% of flow); Tigris is only 18% of area and 53% of flow from Turkey
- Explored the analysis and implications of the dam and water control in the basin
- Everything in this system is severely affected by human intervention – nothing natural remains
- Most existing dams are for hydropower and not storage, though some divert water for irrigation
    - Mardin (Ilisu) Dam could currently hold enough water to control the entire water supply from Turkey to Iran
        - 6 month lag from snowfall / runoff to water availability
    - 28 current dam and 15 planned
- Dates have high water requirement, more than beets; however, people are all converting lands to dates because the labor inputs are low
- Water budget in Kutt Barrage have severely decreased from 1980s until present day (both rainfall is slowing down / natural availability is decreasing and dam is diverting a large amount of water
    - From 15,000 mcm (1980s) to 3,000 mcm (now)
    - 9 out of 10 years they cannot meet the needs of the Hawizeh marsh
- No consistent treaty or relationships between Turkey (controller of dams, water capacity of multiple-year flow) and other countries, which is a major socio-political factor
- If all proposed dams are constructed, it will drastically shrink marsh land and there will also be an overall 50% reduction in water availability
- 500,000 people live in the marshland and rely on fishing for livelihoods
- If you want to maintain 75% of the original marshland, you can only maintain 10% of the current available water
- Amount of water just from evapotranspiration from the man-made lakes could feed 50% of the original marshland
- At the current rate of planned development, the marshland will shrink from 4,000 km^2 to 600 km^2

Session 2: Africa

Presentation: Socio-hydrology through SWAT: Jeldu, Ethiopia and Tana River Basin, Kenya
By: Tracy Baker, IWMI Researcher – Hydrology and Hydrological Modelling

Summary: More work needs to be done to integrate people into modelling environments. One way is to come up with methods, such as using local knowledge, that allow us to delineate and isolate in our biophysical models the ecosystem services people most value.

- Since ecosystem services are people-focused, how can we communicate the information?
- How can we reconcile the biophysical and social sciences?
- This work looked at gender differentiated 3D maps as a drive in SWAT
- Challenge was how to incorporate human perception & value systems
- Traditionally you cannot integrate this type of social information into models
- Spatial data, such as maps, help to reveal things we don't or can't say, and it can give us some understanding about ecosystem dynamics
- We find that people deal differently with time and space and maps can help us understand some of the discrepancies we find in traditional survey methods
- Local knowledge identifies most important resources
    - Therefore necessarily points out ecosystem services, it is connected to livelihoods
    - Can take many forms

- There are cautions, however:
    - Who participates and why?
    - Maps contain private information and make it public
    - Maps have the power to marginalize as well as empower
- How does SWAT fit into this?
    - Male and female maps at Jeldu were drastically different
    - Women focused on soil fertility and men on land usage
    - None and all of the maps are "correct" because all maps, including the researchers' maps have bias. "Correct" is wrong term to use in this context.
    - Maps at Jeldu identified sacred trees, holy water sites, quarry sites, fertile soils
    - Using SWAT allows us to then assess the potential for these different ecosystem services under varied scenarios
    - Different perceptions resulted in a different water balance but the perception guides many decisions, not the water balance
    - Maps can be used to evaluate multiple perceptions of landscape and quantify the impact on ecosystem services
- In Tana we are now interested in exploring if and how the local community perceptions of ecosystems services differ in the Tana River basin

Presentation: Using SWAT to assess Ecosystem Services in within the Tana River Basin for the Nairobi Water Fund
By: Fred Kizito, CIAT Senior Scientist – Soils

Summary: An ecosystem services approach is being used in the Upper Tana River Basin where there are strong linkages across the soils-water-ecosystems-livelihoods interface. SWAT can be used with other ecosystem services and socioeconomic models to better understand this system with complex upstream – downstream challenges.

- The area is a unifying source of livelihoods
- 90% of Nairobi's water comes from the basin, though Nairobi is not in the basin
- 60% of Kenya's hydropower comes from the basin
- Upper basin impacts lower basin: flood recession agriculture and Tana Delta is of international significance (Ramsar site)
- Upper Basin is highly prone to erosion and sedimentation
- The goal of the project is to protect vulnerable landscapes at the course of the issues and decrease costs of water purification
- Private industry is contributing to this effort financially because they see the tradeoff benefit
- The project is also putting in efforts to look beyond agriculture as the culprit and identifying point sources such as quarries or roads
- They are also using the RIOS model and InVEST in this work; linking with SWAT

Session 3: Latin America

Presentation: The use of SWAT model for assessing water-related ecosystem services
By: Natalia Uribe, CIAT GIS and Hydrological Modelling

Summary: Project overviews from Latin American where an ecosystem services approach is being used.

- Sites: Peru, Columbia, Ecuador, Mexico
- Future work: improve land cover and soil databases for SWAT according to local conditions
- Increase collaborations with CGIAR – SWAT teams
- Looking at Payment for Ecosystem services in many areas
    - SWAT has proven useful for this work because it allows for analysis of heterogeneous landscapes
    - Can look at tradeoffs for Payment for Ecosystem Service work under different land use scenarios
    - Can update the database for local conditions
- As an example, they have looked at the impact of conservation tillage on both water quantity and quality in potato-based rotations

- In Peru, they are looking at defining specific areas of the landscape that provide hydrological services and considering Payment for Ecosystem Services approaches
- SWAT also allows all of this work to be done under different potential future climate changes

Presentation: Modeling conservation practices in APEX: From the field to the watershed
By: Wendy Francesconi, CIAT Environmental Scientist – Decision and Policy Analysis

Summary: Within the USA, as part of the Conservation Effects Assessment Project, SWAT and APEX are being used to assess tradeoffs among different management practices and impacts to ecosystem services. This presentation shows how these tools are being used together to scale up to landscapes.

- SWAT and APEX are looking at different but complimentary scale issues
    - SWAT: watershed, in-stream processes
    - APEX: field scale, edge of field processes, more detailed and allows for multiple cropping systems
- Two experimental sites were presented: Maumee Basin and Lake Erie
    - There are issues with Algae Blooms
    - From 1975 – 1995 the algal bloom decreased, but then from 1995 – 2009 it increased and no one knows why
- In APEX, 1 – 3 different conservation practices are implemented for each farmer
- The modeling results indicated that even after implementing conservation practices, there was still an increase in DRP and SN losses
    - Combining 3 practices worked better than implementing only 1 or 2
    - Tree and shrub planting was most successful
    - Filter strips and grassed waterways were also good
    - Conservation crop rotation + cover crops + no till was the most successful combination of three factors
- Exploring linkages to AIRES now for ecosystem services valuation

Session 4: Central Asia – MENA

Presentation: Valuation of ecosystem services for improving agricultural water management in Kazakhstan
By: Vinay Nangia, ICARDA Agricultural Hydrologist

Summary: working in areas where many decisions are made, but not necessarily founded on sound science. Focus was on getting science into policy by building capacity and demonstrating the usefulness of the models when data are available and the models can be applied.

- Using InVEST linkages to SWAT
- Majority of irrigated agriculture is around Turkestan
    - Chandara Reservoir is the focus
    - Volume of water fluctuates 10 – 12 times from winter to summer
    - Major ESs looked at here are food / water, erosion control, nutrient cycling / pollution, recreation / tourism
        - All are supported by the dam
    - Working to identify the users and abusers of the water by mapping all the different water users
    - Idea here is that the people benefitting from decreased sediment should have to pay somehow
        - Donate 8 hours of their time to plant trees
    - There have been a lot of activities in this basin, but none seemed to have any scientific basis
    - Need to move people away from degraded areas and move people from flood to drop irrigation
    - By improving efficiency of agricultural management, this will improve many different ecosystem services downstream
    - There is a need to find farmer incentives
    - They have focused a lot on locally available technologies for female farmers

- One other aspect of the project has been to train others (government level workers) in using the model as a way to demonstrate why they need data access
  - If local offices won't give the project local data, then the project can only give them limited results
- Using InVEST to look at what and where might be the best returns on investments for conservation measures and natural capital

Presentation: Water availability and demand analysis of the Indus Basin by SWAT model
By: Usman Khalid Awan, ICARDA Groundwater Hydrologist

Summary: This presentation focused on how SWAT can be used to address complex ecosystem services provision in an irrigation scheme with numerous canals and water transfers.

- Indus Basin; transboundary issues: Afghanistan, Pakistan, India, and China
- Quantifying nitrogen dynamics and flows
- This presentation showed that there can be highly complex linkages within a river system, that also included a network of human-made canals and so the question was, is SWAT able to address this?
- To set up SWAT, the canal command areas and river reaches were combined to delineate the overall system.
  - Issues that cropped up were how to route the water within SWAT.
  - There was an irrigation water deficit meaning that some HRUs received no water
  - This meant that additional methods has to be integrated to more accurately describe the system
  - For the canals, the parameterized as user-defined streams
- Other issues that came up in the model are that areas with light soils were receiving more recharge
- GW recharge was determined at the HRU
- Crop yield data were used to calibrate the model, though data were difficult to come by
- Ultimately there was a large gap between supply and demand, even when groundwater was added into the system
- Next phase is to look at nitrogen dynamics and flows to mitigate losses from agricultural systems

Session 5: India, South Asia, and Southeast Asia

Presentation: SWAT work past, present and future in India
By: Rajesh Nune, ICRISAT Visiting Scientist – Resilient Dryland Systems

Summary: This presentation focused on using SWAT with a Groundwater bucket type model in MATLAB. The work was carried out in the Krishna Basin where land use changes have resulted in decreased stream flows.

- This is another complex system to mode because there are many small structures throughout the basin such as tube wells and dug wells
  - To address this, all small structures were aggregated at the Subbasin level
- During the time of interest rainfall patterns showed no significant reduction and so it does not explain the decrease in stream flow
- A simply groundwater bucket model was used in MATLAB and linked to SWAT
  - At this stage, the model still used the same boundaries for groundwater and surface flows
  - There was a clear impact of all the small structures when aggregated on streamflow
  - During the time, it was noted that irrigation had doubled, recharge had increased, AET had increased, but that streamflow decreased significantly

Presentation: Defining and measuring watershed sustainability using SWAT
By: Aditya Sood, IWMI Senior Researcher – Integrated Hydrological Modelling

Summary: This work described the development of a framework to assess watershed sustainability by producing an index.

- A hypothetical case study was presented
  - Recharge potential
  - Small watershed in Delaware where the land use is highly fragmented

    - Areas with good recharge potential should be left natural and those will low recharge potential should be used for agriculture
    - Develop the watershed in such a way to provide minimum ecosystem services to stakeholders without prohibiting access to future services
- Systems need to be able to recover from extreme perturbation
- The index proposed combines reliability, resilience, and vulnerability and then a range of this index is considered acceptable
- A wide variety of indicators are combined in the index: social, environmental, biodiversity
    - All are indicators that can be developed from SWAT outputs
- Index uses an additive weightage
- Ultimately this index allows you to measure changes in ecosystem services that a watershed provides and this index can be compared across different scenarios for development of the watershed

Presentation: Ganges aquifer management for ecosystem services
By: Lal Muthuwatta, IWMI Regional Researcher – Hydrological Modelling & Remote Sensing

Summary: This presentation illustrated a method for locating the most suitable areas for Ganges Aquifer Management Ecosystem Services (GAMES) activities.

- Goal: during the dry season, create sub surface storage and during the wet months, recharge this storage
- Desired outcomes: reduce floods downstream, increase flows during low flow periods and increase overall water supply for irrigation
- SWAT was linked to MODFLOW and pumping was simulated near the river
    - Challenge is the need for more data to calibrate the model
- This work looked not just at topographically delineated areas but also politically delineated management areas
- It was a nested scale study that focused on exceedance probability

Session 6: Global Applications

Presentation: Irrigation investment analysis, global water quality assessment and linking SWAT and other socioeconomic tools
By: Hua Xie, IFPRI

Summary: This presentation focused on ways to use SWAT to support policy making at large scales.

- The work is carried out at the country or continental scale using public domain data
    - Data acquisition is primary challenge
- Themes addressed: irrigation analysis and global water quality assessments
- Agricultural water management solutions: investment options for smallholder irrigation
    - This used an integrated GIS-SWAT-DREAM approach
    - SWAT was chosen to estimate crop yields, runoff groundwater recharge, and water requirements for irrigation
    - Model was fit to GRACE and generally in sub-Saharan Africa SWAT and GRACE are in agreement
    - There is a potential for different irrigation
- In South Asia (NW India), SWAT was used to replicate groundwater decline trends
    - Also to assess groundwater under climate change
- Work has also been carried out to look at global nutrient loadings
    - Model building: topography, soil, precipitation, temperature
    - Linked to global loadings of nitrogen by 2050
- Future work will include coupling SWA with decision models on socioeconomic side / results interpretation

Day 2: Establishing the Ecosystem Services to be addressed

The second day of the workshop was intended to facilitate discussions among members about needs they see across the various CGIAR centers, present ideas on opportunities for collaborations or model development, and finally to work on developing an initial set of ecosystem services for which guidelines will be generated in 2015.

Session 1: Discussion

The day opened with a discussion of any general SWAT questions that people may have, as well as concerns, challenges, or different approaches being undertaken. Main points are captured below.
Data

A discussion was had about working in data scarce regions and how other models that have been calibrated and validated can prove useful in SWAT calibration efforts. For example, SEBAL, GRACE, and MODIS ET have a potential use at basin scales in particular to judge the performance of SWAT. ***This is an area the community of practice would like to work on more.***

A discussion was then had about CFSR data. Rainfall poses the greatest uncertainty in a model and in many regions rainfall data are lacking. This leads many people to using global datasets such as CFSR; however, people are noting there are many issues with these data in mountainous regions or in areas with few than 400 mm of annual rainfall.

Another topic discussed in terms of overcoming data shortfalls is to work more with social scientists to gather information through famer interviews (Local knowledge about systems), as well as work more closely with government experts (*e.g.*, extension agents) as well as use government statistics to develop model inputs. Some of this is donor driven because funding is often contingent upon meeting milestones and so people inflate data to continue receiving funding. Large political changes in countries can also interfere here.

Usman (ICARDA) brought up the issue that different centers have different data access policies and this can be a problem when trying to work together. Some of this should dissipate as we begin to move toward Open Source data management policies.

Complimentary models

Next the group explored complimentary models people are using. Some presentations already discussed this and had examples of using SWAT with other models to assess ecosystem services. Some examples of models discussed were **InVEST**, FRAGSTATS, MODFLOW, AQUATOX, **RIOS**, **ARIES**, **APEX**, AquaCrop, and CROPWAT (**bolded tools** represent tools participants discussed in their presentations). It was decided by the community members that some information on SWAT co-use with other models should be included in the CGIAR SWAT Ecosystem Services Guidelines.

Irrigation and Dam Operations

This was an issue cited by many members as a problem. In many of the countries where we work there is a lack of planning or any records. Some pointed out that they find governments often inflate data in a positive way, making it very difficult o model things correctly or to know where errors are in the model. This is a challenge that we need to overcome.

Working with Social Scientists

It became clear that some challenges can be more effectively overcome by working more closely with social scientists. There is a give and take between culture and agricultural best practices sometimes. There is a clear need to better account for multiple levels of stakeholders when developing scenarios. This is not happening and so we need to work on making this a priority in projects that require scenario development.

2015 SWAT Community of Practice

We decided this will be by invite only and that Tracy and Srini will take care of this. Mostly the meeting will again consist of CG people; however, there is always a need for some focused outside perspectives both outside CG as well as outside of hydrology.

In 2015, more focus should be put on idea sharing and developing cross center projects. ***This is an area the community of practice would like to work on more.***

We looked at the IWMI Water Portal and how IWMI puts models up on line and that some of this may be helpful to others. Also, maybe other members of the community would like to upload models here. Permissions can be set as required. People liked this idea and we discussed how in the United States all basins are online and users can download basic data files and work with these to further develop and refine models. The group agreed that we need to move toward this type of system rather than continually recreating models. Also, we want a way to provide feedback on models or data downloaded and the technology must be low bandwidth. ***This is an area the community of practice would like to work on more.***

We learned that QSWAT is under development. This was a good announcement to hear as the CGIAR system moves toward a completely Open Source environment. There are opportunities to get involved if people want to do so.

Rainwater harvesting

This is an area that Vinay (ICARDA) is actively on with Srini. They are looking at ways to capture this in SWAT.

Climate Change

Srini informed the group that there are developments under way for producing CMIP3 and CMIP5 climate change scenarios that are downloadable similar to CFSR data sets and preformatted for use in SWAT. The following data are available:

- CMIP3 – 9 models, 3 scenarios, Downscaled using BCBS
    - Available from SWAT website
    - Through 2095 daily
    - 0.5 x 0.5 degree gridded
- CMIP5 – they are working on this but only two models and two scenarios are available for Africa and MENA regions. These will be 22 km grids. The US and Europe will be available as 11 km grids with two models and all scenarios, and, the rest of the world will be available as 44km grids with 2 models, and all scenarios.

Crop suitability under climate change

Fred (CIAT) indicated to the group that there are opportunities to work on this together and to look more closely at some of the work IFPRI is doing in this arena, make contributions.
Fred is going to work with Srini on applying degree days for crop growth in the Tana.
Wendy (CIAT) and Hua (IFPRI) are going to work on a paper with Srini on assessing crops that will be most suitable in the future.

Database of crop, soil conditions, and climate

Aditya (IWMI) identified this as a high priority area that the community of practice can work on together. CIAT is already working on Big Data issues and creating databases. We need to collectively look more into this and how to contribute because these databases will be useful for developing our models going forward.

Guiding Principles

Fred (CIAT) suggested that we have a section on how to use different types of data and approaches in the guidelines document that we will develop. We have discussed some of these in the workshop and need to make sure we capture them in the final guidelines document.

Data Mining

This is an area where we need to focus more attention (Tracy – IWMI) so that we can develop a set of regional parameters for use in SWAT (Aditya – IWMI). It should be a high priority area.

Tracy (IWMI) stressed the need for developing a database of indigenous land use practices. This was well received and considered a high priority area that the community would like to address soon. The group agreed that modern doesn't always mean better and so we need to work more on this. ***This is an area the community of practice would like to work on more.***

Fred (CIAT) suggested that we look more closely at the WEAP databases and harvest data from there as well. The database is quite large.

Tracy (IWMI) suggested that we mine data from the Tropical Plants Database (prota4u.info).

Session 2: Gallery Walk

To collectively decide which ecosystem services the SWAT Ecosystem Services guidelines should focus upon, there needed to be a common understanding of the language of ecosystem services. During this part of the workshop, the facilitator employed a Gallery Walk discussion technique. Gallery Walks are useful in that they get participants walking around and being actively engaged. For the Gallery Walk, four stations were set up around the room. At each station was an easel with a large piece of paper and a photo of an agricultural landscape. Participants were divided into group of 4 – 5 people, with each group containing at least one volunteer member who was not a hydrological modeler but were instead focused on either ecology or social systems. The facilitator used the image (Figure 6) from "Figure 1" in the *CGIAR WLE Ecosystem Services and Resilience Framework* to illustrate what type of results the activity would generate.

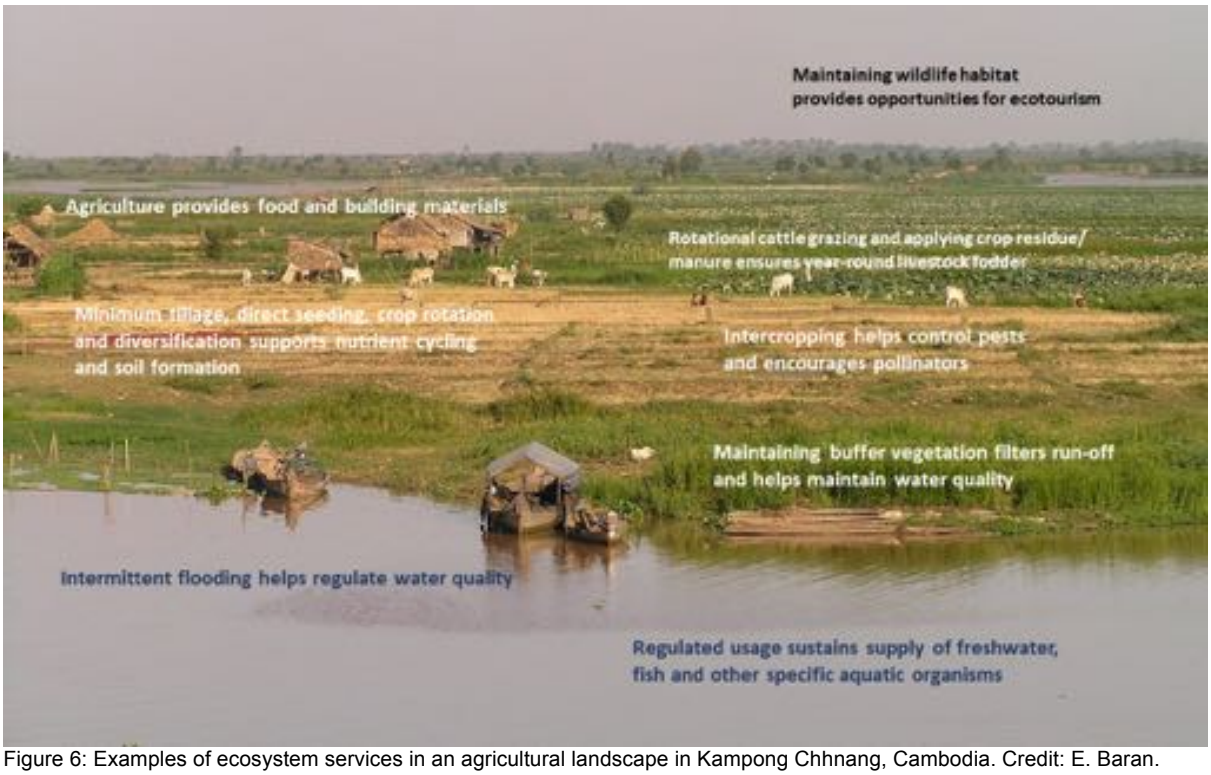

Figure 6: Examples of ecosystem services in an agricultural landscape in Kampong Chhnang, Cambodia. Credit: E. Baran.

Groups were assigned to an initial photo and given two minutes to write as many ecosystem services as they could identify. This would take place over four rounds with the first round being for the identification of provisioning services, the second for regulating services, the third for habitat services, and the fourth for cultural services. After each two minute round, groups rotated to a new photo such that each group visited each photo once and identified one category of ecosystem services. Results of the exercise are shown in Figures 7 – 10, with notes on post discussions about each picture and potentially linkages to SWAT shown as sidebars.

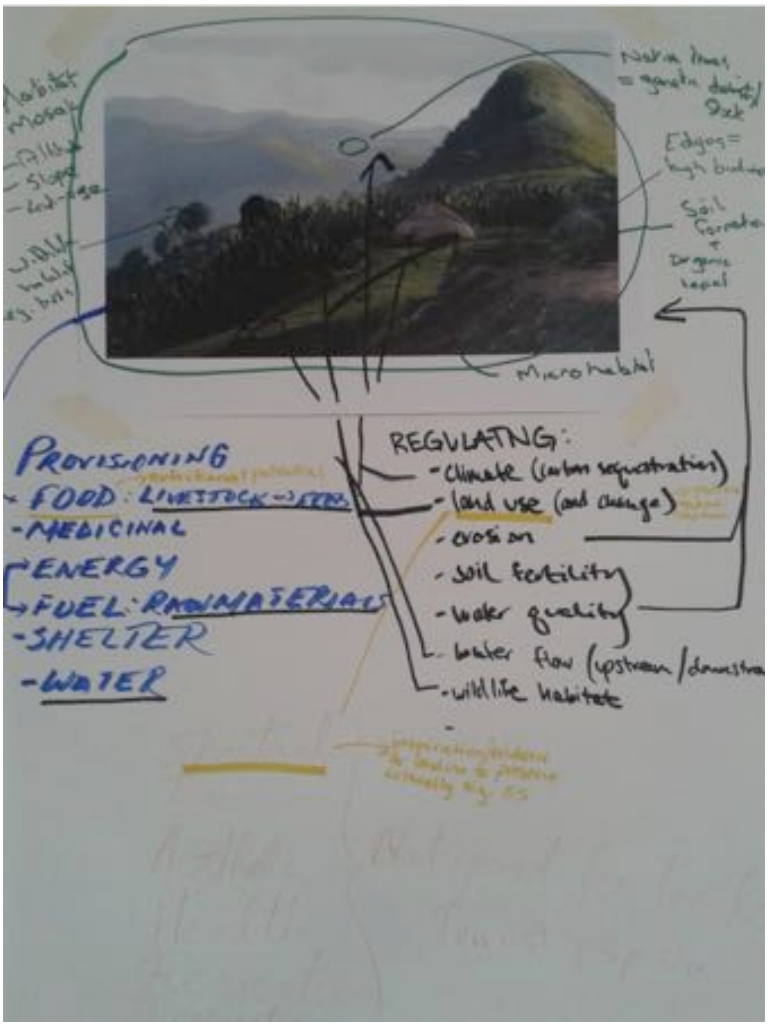

Figure 7: Example of an East African Highlands landscape.

Ecosystem services and SWAT output files identified during the Gallery Walk

Food ESs
How land use changes:

- Biomass productivity in the HRU and .mgt files
- Nutritional potential

Land use and Spiritual linked ESs:

- Information comes social scientists to modelers
- Indication of a specific land use value to the community
- .rch and .sed files in SWAT
- Scale specific
- Maybe create indices from multiple scenario outputs?

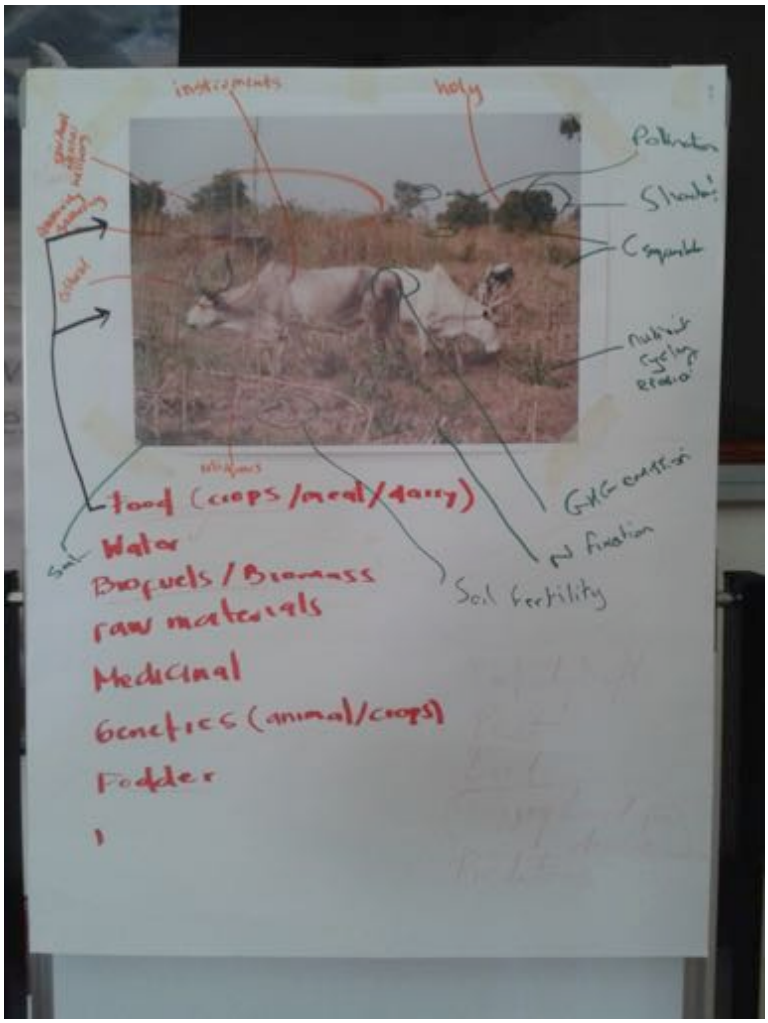

Figure 8: Example of a West African livestock dominated rangelands landscape.

Ecosystem services and SWAT output files identified during the Gallery Walk

Water and Biomass

- HRU: Water balance / Soil Moisture
- HRU: Biomass

Nutrient Cycling: Soil erosion and Fertility

- HRU: Directly get from HRU output file
- .mgt output file

Grazing land

- .mgt file: Biomass

Tradeoff analysis: look at marginal land conversion to high productivity through land management

Preferred food sources for animals.

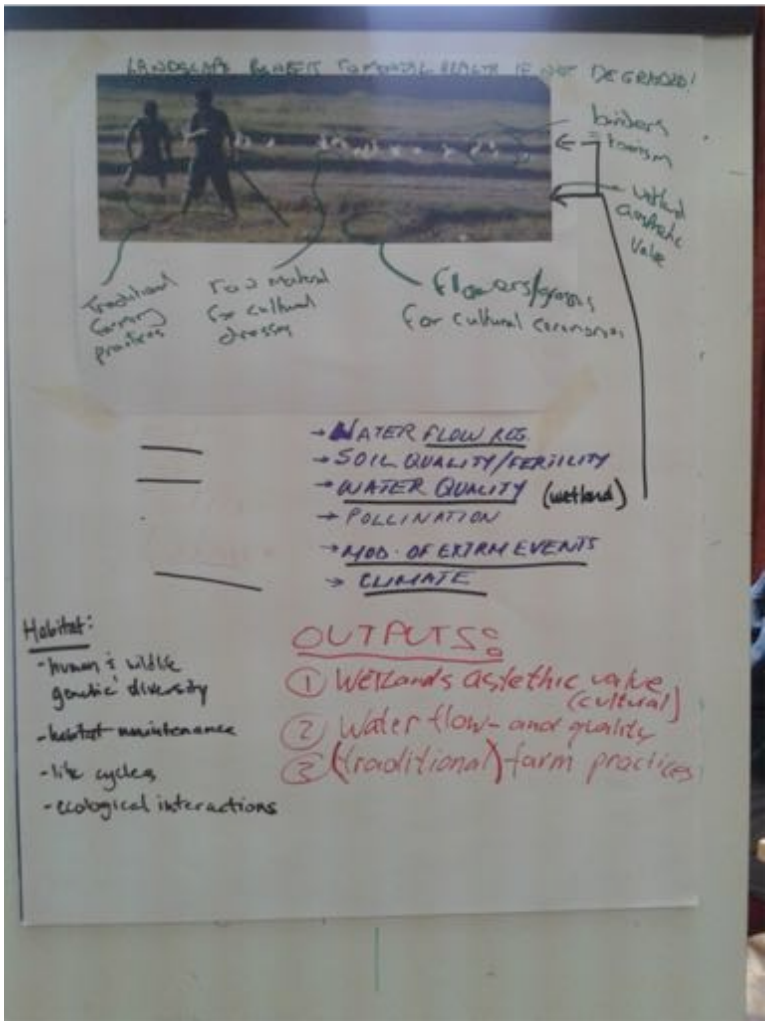

Figure 9: Example of a South Asian paddy rice landscape with wetlands developing.

Ecosystem services and SWAT output files identified during the Gallery Walk

Wetlands: Aesthetic value

- SWAT can identify size of wetlands, amount of water
- .rch file will give amount of water coming in

Water flow & quality

- HRU level information: soil moisture, baseflow, nutrient concentration

Traditional farming practices

- Scenarios can be used, diff farming practices can be modelled to look at impacts
- Tillage practices in output.mgt

Wetlands impact on water quality from urban areas and flood mitigation

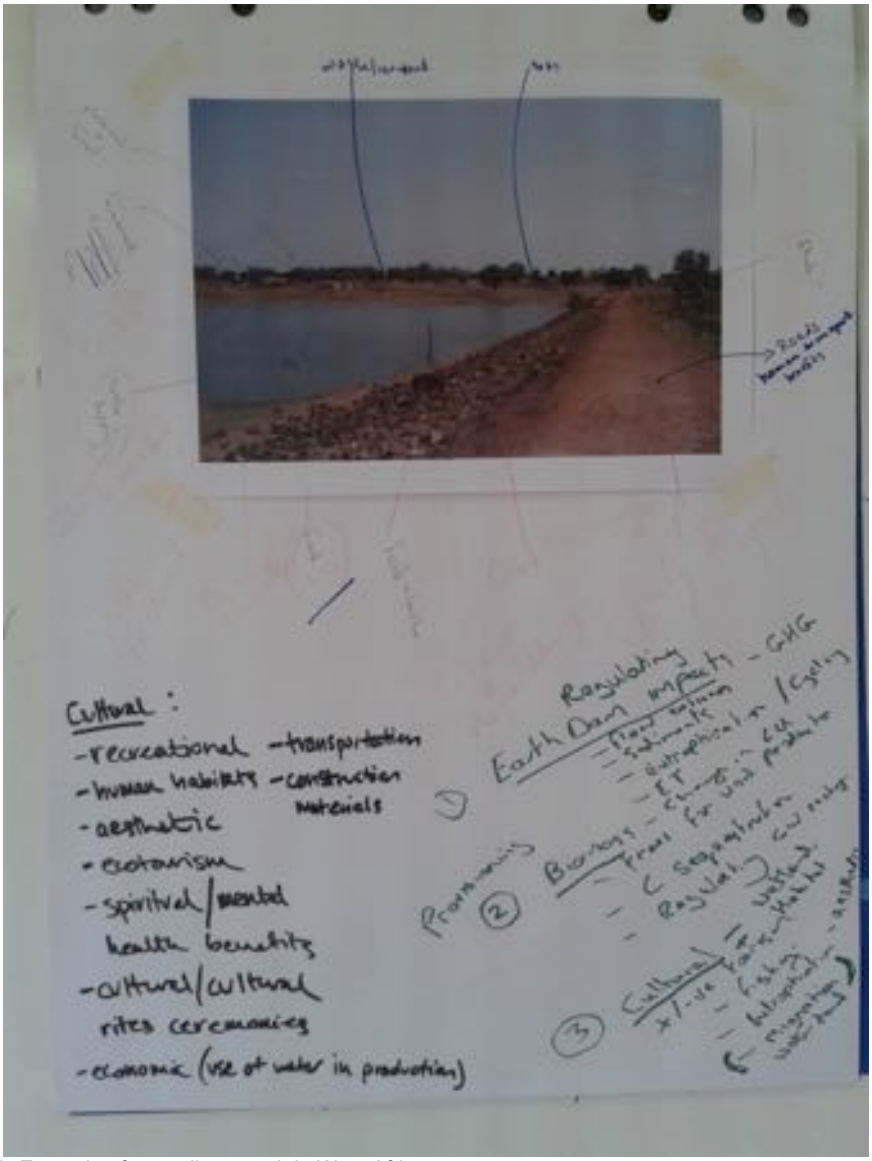

Figure 10: Example of a small reservoir in West Africa.

Ecosystem services and SWAT output files identified during the Gallery Walk

Flow extremes, sedimentation, and eutrophication

- .res, .sed

Biomass and provisioning with tradeoffs among tree cover, crop land and wetlands

- HRU, .mgt

Cultural

- What have you gained and lost?
- Do people have access to more fishing?
- What was on this landscape before?
- Are there problems resulting from eutrophication?

What about migration? Will more people move into this area now? What is consequence?

During this portion of the workshop, it was particularly beneficial for the community to have several volunteers from outside not only the community of practice, but outside of hydrological sciences. We had scientists who focus on water policy and governance, technology implementation, gender, sanitation, and ecology. During the exercise, their role was to "ask the tough questions" and not allow the modelers to stay focused on biophysical aspects only. The exercise was well received and resulted in participants expanding their discussions to think more about the application of models and in particular how results can influence people.

Session 3: Ecosystem Services Selection

After completing the Gallery Walk and further group discussions, a brain storming session was held to establish 2 – 3 ecosystem services within each of the four broad categories of Provisioning, Regulating, Habitat, and Cultural. First, generalized services were selected and then as the writing process began; community members would have the opportunity to refine or specify in the context of how SWAT can produce a quantitative measurement either directly or as a proxy for the more specific ecosystem service.

General services decided upon for the guidelines were:

- Provisioning
  - Food (fish, game, fruit)
  - Water (hydropower, drinking water, industrial, irrigation)
  - Raw materials (building – timber, bamboo)
  - Livestock forage
- Regulating
  - Carbon sequestration
  - Land use change / Degradation or Rehabilitation (erosion, sedimentation [water quality], nutrient balance)
  - Flow regulation (flooding, environmental flows, dams, irrigation, structures)
- Habitat
  - Wetlands
  - Environmental Flows and Water Quality
  - Natural Vegetation
- Cultural
  - Ecotourism
  - Spiritual
  - Cultural Lands (rice paddy, grazing lands)

Day 3: Write Shop

The final day of the workshop was a continuation of writing collaboratively about the ecosystem services selected on Day 2 for the initial SWAT Ecosystem Services guidelines.
Priority ecosystems to be worked on during day three of the workshop were selected; they were: Hydropower, Crops (human food, livestock feed, biofuels), Water (water conservation, storage, domestic water use, and industrial), carbon sequestration, other food (fish, game, fruits).

The community members worked in the CGxChange to begin developing the SWAT Ecosystem Services Assessment guidelines. This will allow the group to continue working collaboratively on the guidelines once they are no longer together.

For each service, they are including short description that includes the landscape capacity to produce a given service. For example, in the case of food this would mean some understanding of calories and dietary/nutritional diversity that would happen with an alternate landscape composition and configuration (WLE). For each service, photos will be included for illustrative purposes or there may be other types of graphical representations given. SWAT outputs will be detailed for a given service such as biomass yield in tons / ha, maps, indicators of temporal and spatial scale, model connections, and SWAT inputs. The group also decided that associated constraints should be included. This could mean the development in SWAT of an "environmental file" as an output (where both space and time can be assigned).

Recommended guidelines for undertaking ecosystem services assessments using SWAT will be published by the CGIAR SWAT Community of Practice with the support of WLE in 2015.

Appendix A: SWAT Community of Practice Survey

The following illustrates the survey sent out to CGIAR Centers in establishing the SWAT Community of Practice. There were 63 respondents to the 10 question survey.

1. Please provide your contact information
   - Name:
   - Center:
   - Country:
   - Email Address:
2. Are you currently a SWAT modeler or a SWAT model outputs user?
   - Yes
   - No
3. Please indicate which SWAT interface(s) you have used, are currently using, or are planning to use. Note: Select all that apply.
   - SWAT
   - ArcSWAT
   - ArcView SWAT
   - AGWA
   - MapWindows SWAT
   - SWAT Editor
   - SWAT-CUP
   - VizSWAT
   - SWAT-WB
   - Don't Know
   - Other (please specify)
4. How many years have you been a SWAT user? Note: Please answer 0 if you have never used SWAT, but are planning to use the model, or if you have had training only.
   - Years:
5. Which general regions have you worked in with the SWAT model? Note: Select all that apply.
   - None
   - North America
   - Central America
   - South America
   - Europe
   - North Africa
   - Sub-Sahara Africa
   - Asia
   - South Asia
   - Southeast Asia
   - Australia
   - Feel free to provide more specific details:
6. What are your primary interests in SWAT in your projects? Note: Select all that apply.
   - Hydrology
   - Water Quality
   - Best Management Practices
   - Climate Change
   - Land Use Change
   - Watershed Planning
   - Scenario Development and Testing
   - Assess Ecosystem Services
   - Assess Gender Differentiated Impacts of Landscape Change
   - Other (please specify)

7. What size watersheds or basins do you typically work in with SWAT? Note: Select all that apply.

< 1 000 ha
1 000 – 50 000 ha
50 000 – 500 000 ha
> 500 000 ha
Other (please specify)

8. Would you be interested in joining a CG-wide Community of Practice focused on SWAT usage?

Yes
No

9. Would you be interested, and have time, to assist in organizing or facilitating a CG-wide SWAT Community of Practice?

Yes
No

10. Which of the following types of activities would you be interested in seeing from a CG-wide SWAT Community of Practice? Note: Select all that apply.

Annual meeting
Training opportunities
Online community
Write shop organized around SWAT modeling topics
Data exchange
Model development
Database development
Work on calibration methods
Work on uncertainty issues
Methods for output analysis and usage
Develop joint protocols for ecosystem services assessment
Unsure
Other (please specify):

Appendix B: SWAT Community of Practice Workshop Program

Day 1: Wednesday, 15 October 2014

0845 – Arrivals & Registration

0900 Meeting Opens – Welcome

0905 Simon Langan WLE Nile Basin Focal Region Coordinator & Head of IWMI East Africa & Nile Basin Office

0915 – 0930 WLE Focal Basins (Simon Langan – IWMI)

0930 – 0945 Ice Breaker (N-S, Spatial Scale)

0945 – 1015 SWAT Community of Practice Overview & Points to Ponder over next three days (Tracy Baker – IWMI)

1015 – 1030 Ecosystem Services – Some Definitions (Tracy Baker – IWMI)

1030 – 1050 Tea/Coffee Break

1055 – 1155 Recovering an Iraqi Wetland (Raghavan Srinivasan – Texas A&M)

1200 – 1310 Buffet Lunch @ ILRI cafeteria

AFRICA

1310 – 1325 Tracy Baker (IWMI) – Socio-hydrology through SWAT: Jeldu, Ethiopia and Tana River Basin, Kenya

1325 – 1340 Fred Kizito (CIAT) – Using SWAT to assess Ecosystem Services within the Tana River Basin for the Nairobi Water Fund

1340 – 1345 Discussion: What were the main ESs identified?

LATIN AMERICA

1345– 1400 Natalia Uribe (CIAT) – Project overviews and intros from Latin America

1400 – 1415 Wendy Francesconi (CIAT) – Project overviews and intros from Latin America

1415 – 1420 Discussion: What were the main ESs identified?

CENTRAL ASIA- MENA

1420 – 1435 Vinay Nangia (ICARDA) SWAT – InVEST Linkages; Central Asia work

1435 – 1455 Usman Awan (ICARDA) – SWAT Modeling for Indus Basin

1455 – 1500 Discussion: What were the main ESs identified?

1500 – 1520 Tea/Coffee Break

INDIA, SOUTH ASIA, SE ASIA

1520 – 1535 Rajesh Nune (ICRISAT) – SWAT Work past, present, future in India

1550 – 1605 Aditya Sood (IWMI) – Defining and Measuring Watershed Sustainability Using SWAT

1605 – 1615 Lal Muthuwatta (IWMI) – Ganges Aquifer Management for Ecosystem Services

1615 – 1630 Discussion: What were the main ESs identified?

ESs, SWAT, and ECONOMICS

1630 – 1645 Hua (IFPRI) – Irrigation investment analysis, global water quality assessment and linking SWAT and other socioeconomic tools

1645 – 1715 Recap of Presentations (Tracy Baker), Wrap-up and Close (Regional issues confronting the use of SWAT application to assess ESs)

1730 Bar-B-Que Social @ ILRI

Day 2: Thursday, 16 October 2014

0830 – 0845 Opening Remarks and brief recap of Day 1

0845 – 1015 Discussion of Pressing SWAT Questions, Concerns, Challenges, New Avenues and Approaches

1015 – 1030 Tea/Coffee Break

1030 – Organize into groups for ES Gallery Walk Exercise

1035 – 1105 ES Gallery Walk

1105 – 1200 Finalize ESs that will be illustrated in the guidelines

1200 – 1310 Buffet Lunch @ ILRI cafeteria

1310 – 1340 Spatial scale issues and how to confront

1340 – 1440 Outputs to measure in SWAT for identified ESs (new groups, based on ES choice is possible)

1440 – 1500 CG xChange Use – Select writing groups

1500 – 1520 Tea/Coffee Break

1520 – 1530 Plan writing tasks / Division of Labor w/in your group

1530 – 1700 Organize group writing plan; start writing

1700 – 1710 Wrap-up and Close

1830 Depart from ILRI reception area for Cultural Show and Dinner at Top View.

Day 3: Friday, 17 October 2014

0830 – 1030 Write Shop – All Day

1030 – 1050 Tea/Coffee Break

1050 – 1200 Writing

1200 – 1300 Lunch @ ILRI cafeteria

1300 – 1500 Writing

1500 – 1520 Tea/Coffee Break

1520 – 1620 Way forward for your group (present to the overall group an overview of what your group has put together and where you will go from there to finalize your sections)

1620 – 1715 Writing deadlines (we want to have the guidelines ready to present at SWAT International Conference), where do we go from here, next year, pressing SWAT issues and priorities for focusing

Workshop Participants

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