Groundwater in sub-Saharan Africa: Implications for food security and livelihoods

2010 Annual Progress Report to the Rockefeller Foundation - Narrative Aspects

EXECUTIVE SUMMARY

Key Findings to Date

Our preliminary findings suggest there is likely to be considerable potential for further groundwater use in a number of African countries where we have been able to focus our research efforts. In Ghana, for example, 5.8 Mha of land area has agricultural groundwater development potential that is good or better, which is three-fold higher than the total area currently under irrigation. In northern Ghana we are finding that groundwater irrigation is not only more widespread than previously envisaged, but is profitable as well, although complex tenural arrangements, labour-intensive maintenance of wells, high cost of inputs, lack of access to credit and lack of extension services for dry season farming are creating impediments. In Uganda, where little or no groundwater irrigation currently exists, groundwater-based irrigation is the most favourable option in the north of the country where the landscape is unsuited to surface storage and highly suitable aquifers are present. In Ethiopia, we are finding that smallholder farmers with higher, year-round access to irrigation water through the use of groundwater are able to produce higher-valued, marketable vegetables. Some of the constraints identified in Ghana would appear to be generic, such as limited access to credit to support infrastructure development. It is becoming increasingly apparent that access and availability of knowledge on the groundwater potential is a major universal constraint that we are working to address through this research.

Overview of the major activities

- The groundwater conditions of 15 African countries, including virtually all AGRA countries, have been documented in a thorough and systematic fashion. In most cases, this is the first time such an analysis has proceeded at these scales. The set of reports produced go beyond resource assessment to cover usage, water quality issues, socio-economics and institutional arrangements and will are currently being synthesized into a book that is intended to provide a substantial knowledge-base for groundwater practitioners, managers and investors. It reveals that in some countries groundwater-based irrigation is flourishing (eg. Ghana, Ethiopia). In other countries hardly any groundwater is used for irrigation (eg. Uganda, Mozambique) but large scope exists with greater availability of information.

- Identifying prospective areas for groundwater development is an issue of great importance where information is scant and is being directly addressed at the national and sub-national scales. Different approaches to mapping aquifer suitability are being trialled in Ghana and

the outputs verified against field observations. The results appear promising with large areas being identified as being potentially suitable for agricultural development. Journal papers are already emerging and the findings will be communicated to local and international audiences in 2011. The outputs are currently being used to support groundwater development projects by IDE in Ghana and similar interest has been expressed in Ethiopia and Mozambique.

- Field investigations have commenced in northern Ghana and the Tigray region of Ethiopia. These areas were chosen due to their high resource value and potentially promising development potential. Various partner groups are examining issues such as the socio-economic costs and benefits of agricultural groundwater use along with assessments of the quantum of groundwater available and its dependability in light of climate change impacts. In both counties the groundwater potential is being assessed and prospective sites for irrigation identified.

- A broad-scale reconnaissance survey is being conducted across at least nine countries that will generate grassroots level information on the opportunities and constraints of groundwater-based irrigation alongside other modes of agricultural water management. The analyses will help provide guidance on an irrigation development strategy most appropriate for SSA's small holder farmers. In northern Ghana where work is most advanced, there does not seem to be sectorial competition for groundwater between irrigation and household uses.

- Novel approaches have been applied to determine the groundwater baseflow contribution to surface water courses for the first time at the pan-African scale. The work serves to provide broad-brush indication of groundwater sustainability from the viewpoint of spatio-temporal changes in groundwater availability and groundwater recharge; which are of the upmost concern when proposing increased groundwater development.

- The project is serving to develop capacity; both within Africa and beyond. Thus far, we have engaged with partners from over a dozen African institutions. Currently seven African MSc and one non-African PhD students are engaged in socio-economic projects on the topics of management challenges, hydrochemistry and groundwater modeling, groundwater potential evaluation, amongst others. .

- Some of the initial findings have been presented at two international forums: the American Geophysical Union Fall Meeting and International Conference "Towards Sustainable Groundwater in Agriculture, both held in San Francisco in 2010.

Introduction

This report summarizes the progress made during the second year of the project: "*Groundwater in sub-Saharan Africa: Implications for food security and livelihoods*", led by the International Water Management Institute, and financially supported by the Rockefeller Foundation as described in the Grant Agreement: 2008 AGR 305, dated 30 October, 2008. It covers the narrative aspects of the project for the second year, covering the period from January to December 2010. The project is due to conclude in December 2011.

Progress on specific activities against the milestones

A brief synopsis on the progress in each activity is given in Table 1. Summaries on the specific activities follow.

Country Reports (activities 1.1, 2.1, 2.2)

Groundwater country reports (CR's) have been prepared in a thorough and systematic fashion for 15 countries, including almost all of the AGRA countries. They include: Burkina Faso, Ghana, Mali, Niger, Nigeria, Ethiopia, Kenya, Malawi, Mozambique, Somalia, South Africa, Tanzania, Uganda, Zambia and Zimbabwe. The reports were prepared by IWMI researchers for selected countries, and supported by consultants from academia and industry for the remainder. For most countries, this will be the first such time that such an analysis has occurred at this scale. These set of documents go beyond resource assessment to cover usage, water quality issues, socio-economics and institutional arrangements and when completed, will provide the foundations for other elements of the project, as well as a substantial knowledge-base for groundwater practitioners, managers and investors.

During the final year of the project the reports will be synthesized into a high quality book that is intended to be a useful resource-base for groundwater practitioners, managers and investors. A series of publications that focus on specific issues (eg. institutions, economics etc) are also intended to emerge from the CR's.

Field studies in the Upper East Region, Ghana

A series of field investigations have commenced in the Upper East Region (UER) in northern Ghana (part of the Volta Basin system) by three teams: CSIR-WRI, UDS and USU examining the groundwater resources from different perspectives. This region was identified with national partners and stakeholders as being of high resource value and worthy of being the focal area for in-depth studies in Ghana.

Studies by CSIR-WRI ***(activity 1.3)***

This component of the project only started in August 2010 after the technical component and administrative arrangements were finalized following a project workshop in Accra, March 2010. The main activities that have been undertaken to date include:

(1) review of available literature on all aspects of groundwater in Northern Ghana, particularly the Upper East Region to identify the various data in existence and the additional data that needed to be collected through field investigations;
(2) collection of secondary data from various sources (HAP, CWSA, GSD, GSS, MOFA etc); and
(3) preliminary field visit to select study sites in the Telensi Nabdam and Bawku West Districts in December 2010. The visit was also used to collect initial groundwater samples for water quality analysis.

Studies by University for Development Studies, Tamale ***(activities 2.3, 2.4, 4.3)***

This component of the research also commenced in August 2010. Like the CSIR-WRI work, it also focuses on the Talensi/Nabdam and Bawku-West Districts, thereby providing socio-economic complimentarity to the hydrogeologically-focussed work by CSIR-WRI. Fieldwork began in December 2010 and will run through to February 2011 as it is primarily during this time of the year that groundwater irrigation is undertaken in the two districts. Preliminary questionnaires were drawn-up and a successful reconnaissance survey was undertaken by the researchers and recruited field data collectors in early October 2010.

A very successful stakeholder workshop was held in the UER on 27th November 2010 in which key stakeholders comprising District Directorates of the Ministry of Food and Agriculture (MOFA), the Ghana Irrigation Development Authority (GIDA), NGOs, farmers, the researchers and field data collectors discussed, in detail, the importance of groundwater for agriculture, the practice in the two chosen districts and the prospects for the future. Many locations of groundwater use for irrigation in the two districts were listed and it was revealed that the use of groundwater for dry season agriculture is much more widespread in the two districts than previously envisaged. Work is on schedule and is anticipated to conclude before August 2011 with the production of two journal papers.

Studies by Utah State University ***(activity 1.3)***

Studies are underway by Utah State University that use a range of so-called "complementary methods" to estimate evapotranspiration (ET) across northern Ghana (including the UER). Accurate determination of the water balance is essential to water resources management, and the uncertainty in the largest component of the water balance (ET) can lead to inaccurate prediction of the water balance. Complementary methods (CM) are attractive for use in this study since they do not rely upon large amounts of data for regional scale ET assessment. One of the methods being tested is the Complementary Relationship Areal ET (CRAE) which is attractive due to simplicity, practicability, and reliability in estimating actual, wet environment, and

potential ET using meteorological data only. A detailing field reconnaissance and collation of the available data was performed prior to commencing the modeling work. Progress is being made in testing a range of CMs and comparing these results against more classic approaches. A typical result is given in Figure 1.

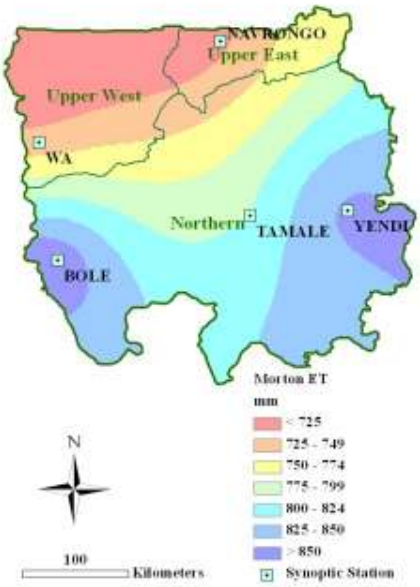

Figure 1. Spatial distribution of actual ET computed using the CRAE method

Stakeholders Dialogue, Accra March 2010 (activity 4.3)

A stakeholder workshop was held on 10 March at the M-Plaza Hotel in Accra. The participants represented a range of government and non-government agencies and institutions: Water Research Institute, Water Resources Commission, Hydrological Assessment Project/WRC, University of Ghana, Community Water and Sanitation Agency, Ministry of Food and Agriculture, Ghana Irrigation Development Authority, Kwame Nkrumah University of Science and Technology, University of Cape Coast. Geological Services Department, University for Development Studies, Savannah Research Institute and STEPRI. Since the forum followed-on from the project workshop in which the participants also participated, the attendees were already well-acquainted with the project, it was arranged as an open discussion to identify what the key issues in relation to groundwater-based agricultural development across SSA with an emphasis on Ghana. The workshop was revealing of many gaps in the available knowledge. The research team is attempting to address as many of the critical issues as can be achievable within the scope of the project.

Field studies in the Tigray Region, Ethiopia (activity 1.3)

Project members from Addis Ababa University, Geological Survey of Ethiopia and the Institute of Development Studies have selected two basins in the Tigray region of northern Ethiopia for systematic characterizing of the groundwater potential. The study includes a review of existing data and field investigations and modeling and is supporting four MSc projects on biophysical and socio-economic aspects. The basins include the 2100 km^2 Raya basin and the smaller adjacent, 800 km^2 Kobo basin situated in the southern part of Tigray. These areas were selected as they are some of the most drought prone districts in the country and more recently some groundwater-based irrigation developments have commenced.

These areas are situated on volcanic basalt terrain, with basalt rock covering the uplands, and reworked sedimentary material infilling the valley floors to thicknesses ranging from several metres to hundreds of metres. A hydrogeological map at 1:50,000 scale will be developed, and combined with a groundwater balance, water quality sampling and groundwater flow simulation modeling to assess the groundwater potential and the anticipated effects of future climate change.

This work commenced in June 2010 and expected to be completed in September 2011.
When this work is completed, it will provide a sound technical basis not only for the selection of prospective sites for manual drilling, but also yield information about the scale of development that can be sustainably achieved in these basins and the socio-economic and institutional issues and opportunities in developing groundwater irrigation.

Groundwater Prospective Mapping (activities 1.1, 1.2)

IWMI researchers have recently undertaken a country-scale analysis of Ghana to map out groundwater potential zones using GIS/RS techniques. Spatial layers of the natural factors that govern groundwater occurrence and availability (geomorphology, geology, slope, drainage density, annual rainfall, land use / land cover and soils) have been generated and integrated into a single map. Results of the analysis were independently tested against borehole yields (based on >2000 measurements). A good correlation was observed between borehole yield and the potential zones mapped. The results suggest that the approach could be of benefit to those who seek to broadly target areas for development. This, relatively simple approach, using data that can be replicated across SSA, was developed with the view to enabling its expansion to other countries if demonstrated to be of value in Ghana.

We are presently undertaking a relatively detailed follow-up study in the three northern regions of Ghana where the access to large database developed as part of the Hydrogeological Assessment Project (HAP) undertaken by the Water Resource Commission (WRC) of Ghana that contains records from over 10,000 boreholes across northern Ghana. This work differs from the country-scale work in two key respects by: 1) being almost entirely based upon drill-hole data, and 2) considering GW Potential not just in terms of water bearing capacity, but also by considering issues such as the accessibility and usability of the groundwater. Here the key factors include regolith thickness, slope, aquifer transmissivity and annual recharge rate. Methods of interpolation between point data and for weighting and combining the individual layers are under

development. It is intended that a map of potential be produced. This map will be further classified using depth to static water level and water quality information since these two factors can constrain groundwater access and the use to which the water is put.

Reporting of this work is expected to be finalized in the first quarter of 2011. The sub-country scale work may not be as immediately transferrable to other regions as the country-scale work due to the higher data requirements. This may or not be an important issue, since we intend to compare the outcomes of the two studies so as to determine the minimum information needs for extending such studies to other regions.

This analysis provides information on the potential areas where groundwater irrigation may occur from a hydrogeological standpoint. Following this, an analysis will be undertaken of factors beyond the hydrogeological domain that more accurately reflect actual areas, taking into account of the suitability of soil types, location of settlements, transportation infrastructure and access to markets.

The groundwater potential maps are not only being tested through a comparison with the existing drill-hole database, but also by their usefulness in supporting current field investigations and drilling efforts in the UER by CSIR-WRI who are undertaking a detailed characterization of the groundwater system to assess its suitability to support irrigation.

The UER is also focal point for the assessment of low-cost manual drilling techniques by IDE acting through IWMI's AWM Research Project. To date, there has been one round of drilling undertaken in March 2010 using the 'sludger' method, a technology brought in from Nepal well-suited to unconsolidated sediments. In the first round of investigations (March 2010), conducted without information from this project, the results were below expectation in that none of the 5 test wells achieved a yield above the 0.7 L/s threshold discharge needed to support treadle pumps. Despite this, the method will be tried in other locations. Currently IDE efforts are being supported by information from this project to better identify potential sites for GW development.

Groundwater Monitoring Systems (activities 1.3, 2.2)

Across SSA groundwater monitoring is limited or absent, and groundwater monitoring systems (GWMS), along with good institutional support, is vital for gathering, collating and analyzing the information that is needed to ensure that groundwater development proceeds in parallel with the effective evaluation and management of the resource.

This work aims to assess the state of groundwater monitoring systems and issues in SSA, with more focus in at least two countries, and develop the set of recommendations on solutions to address these issues in a way that considers GWMS in terms of reliability, cost effectiveness and suitability to the site specific management objectives. The value of the study is that it will provide framework for assessment of the GWMS which can later be applied by implementers which will help them to identify their problems with regard to GWM and address their issue based on this and plan development from there depending on the current needs and management objectives. This work is on track and is anticipated to be a vital part of the GW Strategy.

Regional-scale Assessment of Base-flow (activity 1.3)

The groundwater contribution to watercourses (base-flow) is important for maintaining dry season flows and riparian ecosystems. IWMI researchers have estimated base-flow by means of digital filtering of simulated and observed stream flow records at the African and country scales. Ethiopia was chosen as one of the focal countries for the analysis owing the good hydrograph records in the country (Figure 2). This information is intended to aid in the broad-scale assessment of groundwater availability and groundwater recharge estimation.

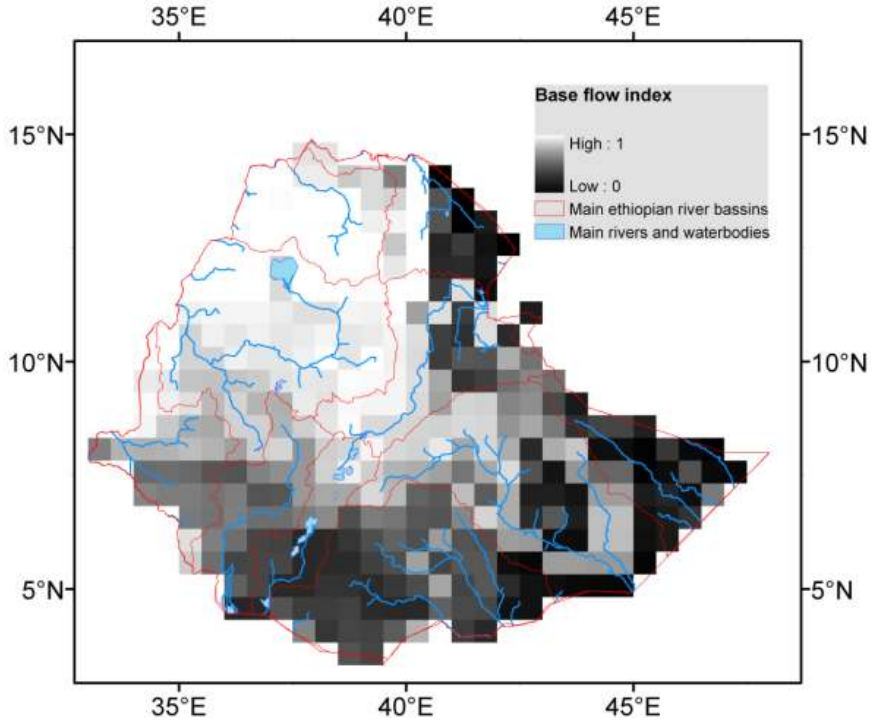

Figure 2: Averaged annual baseflow index for Ethiopia calculated from RDF application over application, monthly discharge runoff data at 0.5*0.5 degree grid

Socio-economic aspects (activities 2.3, 2.4)

A multi-country field study has been developed by the research team to generate grassroots level information and analyses that can guide thinking and discussion on an irrigation development strategy most appropriate for SSA's small holder agriculture. The objective is to make an assessment, through in-depth field research, of the livelihoods and food security implications of

three modes of agricultural water management in small-holder farming systems of Sub-Saharan Africa, viz., [a] Rainfed Farming; [b] gravity flow irrigation; [c] small pump irrigation from surface water sources; [d] small pump irrigation with groundwater. Comparing [a] with [b], [c] and [d] will throw light on socio-economic returns to irrigation investments; and comparing [b] with [c] and [d] will help understand the social cost: benefits of investing in public irrigation versus supporting small-scale private irrigation.

The study is being executed by national researchers in Ghana, Burkina Faso, Mali, Malawi, Niger, Nigeria, Ethiopia, Kenya and Zambia, with the possibility of Tanzania being added shortly.

In almost every case, the work is being executed by MSc students under the careful supervision of their academic supervisor with support and peer review by research team members. The study for Ghana by KNUST in Kumasi commenced first and is most advanced.

Institutional aspects (activities 2.2 to 2.5)

IWMI institutional specialists will be brought into the project in early 2011. The anticipated work program will include a review of existing policies and institutional mapping, with more detailed field work in focal countries involving interviews with policy makers, local NGOs, opinion makers, research institutions to understand formal policy context, their impacts and key actors involved in groundwater utilization. It will include mapping of formal institutions, their functional roles and issues of governance. Interviews will help understand the experiences and impacts of implementing policies so far. If possible, the field work will also include preliminary field visits to understand informal institutions and local technologies for groundwater use for agriculture. In coordination with project team members, detailed field work plans will be developed for further field work that would include key informant interviews, field visits, focus group discussions/workshops and data collection.

Project Publications

Abily, M., Smakhtin, V. and Pavelic, P. (in prep) Base flow estimation derived from recursive digital filter application over simulated runoff time series: Applications at Pan-African and country scales. *Water Resources Research (intended).*

Anayah F. and Kaluarachchi, J.J. (2009) Groundwater resources of northern Ghana: Initial assessment of data availability. Utah State University College of Engineering Report, December 2009.

Gumma, M.K., Thenkabail, P.S., Hideto, F., Nelson, A., Dheeravath, V., Rala, A., and

Busia, D. (2011). Mapping irrigated areas of Ghana at 30-m resolution using remote-sensing data. *Remote Sensing* (available on-line).

Gumma M.K. and Pavelic, P. (submitted) Identifying groundwater potential zones across Ghana using GIS and remote sensing techniques. *Applied Geography.*

Project Communication

- Fathi M.A. Anayah and Jagath J Kaluarachchi, 2010. Can complementary methods reliably estimate evapotranspiration in semi-arid regions? Presented at the 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.

- Tushaar Shah, 2010. Groundwater and agrarian livelihoods: South Asian experience and implications for sub-Saharan Africa. Presented at the International Conference Linking Science with Policy, "Towards Sustainable Groundwater in Agriculture", 15-17June 2010, San Francisco, USA.

Table 1. Revised milestone table

Activity	Title	Description	Area of Focus	Deliverable	Responsibility	Stage of Completion	Delivery date	Key IWMI persons responsible	Others involved
1.1	Groundwater availability assessment based on available information	Collating maps & databases of g'water availability in the study countries. Developing new techniques to create maps of groundwater potential to address data gaps	13 AGRA countries	Country reports on status of groundwater availability for each country. Paper on new mapping techniques	IWMI & country focal points/ consultants	Work is well advanced with work on 17 CRs completed or in final stages	31-Mar-11	Boubacar Barry/Emmanuel Obuobie - West Africa; Bernard Keraita - South/East Africa	Paul Pavelic (review, coord); Gerald Forkuor (new mapping techniques)
1.2	Identification of areas where groundwater can be supply of choice	Building upon #1.1 by mapping rural settlements / livelihood zones to identify where groundwater can have the most impact	Focus countries	Synthesis report that identifies where the groundwater can be supply of choice	IWMI team	Work on this component will commence when hydrogeological evaluaiton is completed	9/31/2011	Gerald Forkuor	
1.3	Analysis of sustainability of groundwater availability	Impacts of rainfall variability & conjunctive use on groundwater availability & sustainability. Modelling the impact of future scenarios of growth in groundwater demand	Selected areas within focus countries	Environmental sustainability assessment of increased groundwater utilization in high potential areas	IWMI team, national partners	Some advances in two of the focus countries	31-Mar-11	Ayenew Tenalem, & Fathi Anayah, Paul Pavelic	Vladimir Smakhtin, Jagath Kaluarachchi, interns
2.1	Review existing literature and collection of secondary data	Describe the state of rural groundwater development and use	13 AGRA countries	Country reports & book	IWMI team & national partners	CRs are now well advanced. The book will emerge this year.	30-Sep-11	Bernard Keraita	Boubacar Barry, Emmanuel Obuobie
2.2	Review of groundwater development policies and strategies	Assessment of institutions, laws & policies governing access to groundwater and its subsequent development and utilization	13 AGRA countries	Country reports, synthesis reports, papers	IWMI team & national partners	Much of the literature review completed through the CRs. Detailed assessment and field work to commence in 2011	31-Dec-11	Fitsum Hagos, Jusipbek Kazbekov, Srinivas Chokkakula	Mark Giordano
2.3	Understanding the potential role of groundwater in improving food security and livelihoods	Activities include site selection, methodological framework development	Focus countries (detailed) and remainig AGRA countries (broad-brush)	Reports, papers on socioeconomic, gender & livelihood impact of present & potential groundwater use at different levels	IWMI team & national partners	Macro-analysis of 13 countries examining importance of groundwater on rural welfare. Draws largely from the CR's. Factors considered include development status (esp. related to water); economic indicators; cost of g/w abstraction and agricultural/livestoc	30-Sep-11	Tushaar Shah & Stefanos Xenarios	Interns, Regional Coordinators
2.4	Opportunities and constraints (O&C) analysis	- O&C analysis using framework developed in a related IWMI project - analysis of technical, economic & institutional feasibilities of GDIs	Focus countries (detailed) and remainig AGRA countries (broad-brush)	Reports that document: (1) constraints and opportunities to groundwater development, and (2) field tested tools to assist groundwater developers / investors in screening GDIs and designing intervention strategies	IWMI team	Broad-based survey covering AGRA countries that assesses livelihood and food security implications for various modes of AWM: rainfed farming, gravity flow irrigation, and small pump irrigation (GW & SW). Tests hypotheses regarding water possession, water	31-Aug-11	Tushaar Shah, Stefanos Xenarios	Interns
3.1	Learning from international experience	Synthesizing past & ongoing research, largely by IWMI, on groundwater governance in Asia, and focusing on Asia's lessons for Sub-Saharan Africa	Asia and Africa	Report and/or paper	IWMI team	Planned for 2011	30-Jun-11	Tushaar Shah and Mark Giordano	
3.2	SWOT analysis for groundwater strategy	Draws upon outcomes of the WP's 1&2 and the synthesis workshop #4.5	Focus countries	Input to #3.3	IWMI team	Planned for 2011	30-Sep-11	Tushaar Shah and Mark Giordano	
3.3	Strategic plan for groundwater development & management in SSA	Accumulates knowledge from the study to cover elements of resource management, investment planning, technology choices, institutional models, regulatory framework, capacity building needs, monitoring, evaluation & information systems	SSA	Strategic Plan Report, Papers, Policy Briefs	IWMI team	Planned for 2011	31-Dec-11	Paul Pavelic	Project Team
4.1	Project inception workshop	Develop plans for each activity. Establish partner agreements. Discuss site selection		Workshop report	IWMI team, national partners & stakeholders	Delayed until March 2010 to enable useful interactions between reseachers and national partners	31-Mar-10	Boubacar Barry, Paul Pavelic & Dominique Perera	Project Team
4.2	Setting up project website	Dissemination of project outputs into the public domain		Project website	IWMI team & IWMI web developers	Phase 1 website developed and will be expanded and updated	31/12/2011	Paul Pavelic & Dominique Perera	Project Team
4.3	National feedback workshops	Engagement with national partners and key stakeholders to share information and seek feedback		Workshop reports	IWMI team, national partners & stakeholders	Ghana completed (March 2010). Ethiopiam workshop scheduled for 2011	30-Jun-11	Paul Pavelic	Project Team
4.4	Midterm workshop	Present initial findings, seek feeback from partners and monitor progress		Workshop report	As above	Scheduled for first half of 2011	31-Mar-11	Paul Pavelic	Project Team
4.5	Synthesis workshop	Collate main findings and gain final inputs for the groundwater strategic plan (#3.3)		Workshop report	As above	Yet to occur (as per plan)	31-Jul-11	Paul Pavelic	Project Team
4.6	High-level policy dialogue	Disseminate findings relevant to policy and decision makers at a specialist workshop		Policy briefs	As above	Yet to occur (as per plan)	31-Oct-11	Paul Pavelic	Project Team