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Research Article

Analysis of Upscaling of Irrigation Development in the White Volta sub-Basin

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Abstract
There is great potential for expansion of irrigated agriculture in Sub-Saharan Africa. The average rate of expansion of the irrigated area needed to achieve the MDG Goal on eradication of extreme poverty and hunger is an unprecedented rate of 5%/year, however the current average rate of expansion is less than 2%/year. The achievement of this target requires strategic accelerated irrigation development. The upscaling of vegetable irrigation in the Upper East Region of Ghana and southern parts of Burkina Faso; all in the White Volta sub-basin within the past two decades is a bright example for harnessing strategies for accelerating irrigation growth across sub-Saharan Africa. The study investigates the irrigation expansion experienced in the White Volta sub-Basin and the drivers responsible for the growth. The study used data from farmer interviews, institutional interviews, field surveys and observations, ground-truthing; literature and satellite images of the study area (2003, 2005, 2007 and 2010). Irrigated areas and irrigation types (private-led and government-led) are observed from the satellite images and differentiated by colour for analysis. The satellite image analysis showed that private-led irrigation systems grew at a rate of 6.4% whiles the existing government-led irrigation schemes expanded their cultivated areas at annual rate of 5.9%. Private-led irrigation represents about 74% of total irrigation in the study area. The factors responsible for the past trend and additional factors are likely to increase irrigation development beyond the current growth rate in the near future.

Keywords
Irrigation Growth Rate — Upscaling Irrigation — White Volta sub-basin — Satellite Image

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Content

Introduction

In sub-Saharan Africa there is great potential for expansion of irrigated agriculture. The average rate of expansion of the irrigated area over the past 30 years was 2.3 percent per year. Expansion slowed to 1.1% per year during 2000–2003 but has since picked up as a result of renewed investments by multilateral and bilateral donors and foundations [12]. For the NEPAD and Commission for Africa to achieve the MDG Goal on eradication of extreme poverty and hunger, irrigated agriculture will need to grow at an annual rate of about 5% which is unprecedented. The achievement of this target requires an assessment of the factors that have influenced past trends of irrigation development. It also requires identification of additional interventions needed to accelerate the future expansion and the potential influence of such interventions. There are triggers that can influence the upscaling of irrigation development which need to be harnessed to help achieve irrigation targets. For example, the rural economy in Sub-Saharan Africa is boosted as smallholders benefit from the opportunity to produce irrigated vegetables for the growing domestic market [3]. Estimates show that by 2030 60% of the world's people will live in cities [6]. As a result Sub-Saharan Africa can take advantage of this trend to trigger the upscaling of irrigated vegetable production by using rural economies. A typical example of the upscaling of vegetable irrigation is observed in the Upper East Region of Ghana and southern parts of Burkina Faso; all in the White Volta sub-basin. Here, the demand for vegetables in the urban centres of southern Ghana has triggered the upscaling of irrigation development during the past two decades [7]. It is interesting to use this positive development to help bring out some of the strategies that are needed in boosting irrigation development across sub-Saharan Africa. This paper seeks to investigate the trend of the upscaling of irrigation development and also the factors (physical, technological, social and economical) that have contributed to these developments. The paper goes further to identify some triggers and interventions that can possibly influence future trends of irrigation development in the study area.

1. Study area

The study was conducted in three transboundary neighbouring catchments located in the White Volta sub-basin, being the Anayari (464 km^2), Atankwidi (275 km^2) and Yarigatanga (357 km^2) catchments where several irrigation technologies have been observed. The study area covers about 1% of the White Volta sub-basin. Forty percent of the Anayari is located in Ghana and the rest in Burkina Faso; 55% of Atankwidi in Ghana and the rest in Burkina Faso; and 80% of the Yarigatanga in Ghana with the rest in Burkina Faso. The study sites have an average annual rainfall of 1100mm/a. In the Ghana section the three catchments are located in the Upper East Region, specifically in the Bongo, Bolgatanga and Kasena Nankana Districts. In Burkina Faso the three catchments are located in the Nahouri Province. There are several water uses identified in the three catchments. These are domestic, fishing, irrigation and urban water supply. The irrigation activities in these catchments depend on the following for their water source: small reservoirs, dugouts, shallow groundwater, riverine water and large reservoirs. The Yarigatanga catchment has a large reservoir irrigation scheme called the Vea Irrigation scheme, which also serves drinking water supply to the Bolgatanga Municipality. All three catchments have small reservoirs, located in both Ghana and Burkina Faso.

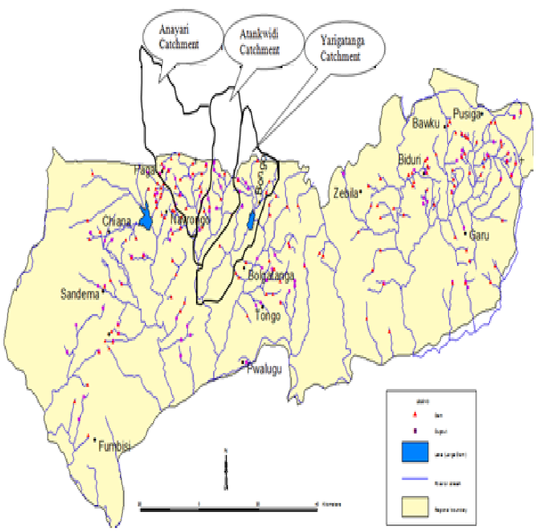

Figure 1. Location of the study sites (Anayari, Atankwidi and Yarigatanga catchments) (Source: adapted from GLOWA Volta Project).

2. Methods

Data used for the study were obtained from: farmer interviews, institutional interviews (Ministry of Food and Agriculture (MOFA) and Ghana Irrigation Development Authority (GIDA)), field surveys and observations, ground-truthing; research reports, project and country reports and satellite images (2003, 2005, 2007 and 2010). Three irrigation seasons being 2006/2007, 2007/2008 and 2008/2009 were observed during the study. A total of 126 farmers and 95 farmers from various irrigation systems were surveyed during the 2006/2007 and 2007/2008 respectively. In 2008/2009 a total of 155 farmers from four different communities (Paga, Vea, Anateam and Telenea) within the study area were interviewed using focus group discussions. Data on small reservoirs used for irrigation within the study area and their cultivated areas were obtained from MOFA, GIDA and literature. The cultivated irrigated areas of the small reservoirs and the surveyed farmers in the study area were measured with GPS for the 2006/2007 and 2007/2008 irrigation seasons. The management of the Vea Scheme provided historical data on the irrigation activities of the Vea Scheme. The image analysis used a series of satellite images of the study area in combination with ground-truthed data and field observations. Different types of satellite images for this analysis were available for the study area. These include Landsat (from 1979), Aster images (from 1990) and spot-images (from 1990 to 2010). Due to the resolution of some of these image types (Landsat: 30mx30m; ASTER: 20mx20m and SPOT: 10mx10m or 5mx5m) and the relatively small sizes of most small-scale irrigation systems (0.01-0.7ha), it was impossible to detect most small-scale irrigation activities in the study area with the Land-sat and Aster images. SPOT images obtained for the study area either lacked quality or fell outside the required period. The most reliable source of satellite images was Google Earth which had historical images for 2003 2005, 2007 and 2010 within the required season and with a resolution of 5mx5m. Annual irrigation activities are intensive between late December and late February, thus satellite images for irrigation analysis have been taken within this period. The Google Earth Images for the area couldn't be downloaded and therefore had to be screen printed. The screen printing was a very challenging approach. A suitable zoom of the image which made irrigated fields visible was determined and kept constant for every window of the screen printing. These screen-printed images were coded to follow the sequence of screen-printing so as they can be merged. The merging of the images was done using AUTOCAD software by uploading the images into AUTOCAD and placing them side-by-side using the codes. The AUTOCAD Software was then used to delineate the irrigated fields. Irrigated areas observed in the satellite images were estimated. Due to the methodology used in producing images in Figures 2 to 5, the scale of the images could not be determined. However, knowledge of the size of the Vea irrigation scheme was used as a benchmark in estimating the area of other irrigation sites. The irrigated areas were divided into smaller pixels and the trapezoid method for estimating areas was applied in estimating the irrigated areas. The figures obtained were compared to the data collected during the ground truthing for validation. In the Google Earth image, all irrigation systems observed are traced and coloured. These include the large-scale irrigation, small reservoir irrigation, shallow wells irrigation and riverine pump irrigation. Irrigation activities are grouped into two types: government-led and private-led irrigation systems. The government-led irrigation systems are the large-scale and small reservoir irrigation with the remaining irrigation systems making up the private-led. There are two reasons for grouping these irrigation systems as such. Firstly, the driving forces behind the development of these technologies are different. Differentiating the two types gives more clarity as to which type of investment is behind the expansion of irrigation in the study area. Secondly, some of the shallow groundwater technologies such as temporal shallow wells, permanent shallow wells and riverine alluvial dugouts are mixed up in the same location and as such cumbersome to distinguish on the image. To make the distinction between irrigation technologies simple, a common factor for these technologies is used. The common factor amongst these technologies is that they are all private-led, thus the choice of private-led and government-led irrigation systems. The Google Earth images obtained over the years (2003, 2005, 2007 and 2010) were limited in aerial coverage over the study area. For consistent analysis, observation windows common to all the years were outlined for all three catchments (see the red outlines in Figures 2-5) and used as the area of analysis. Thus the trend of irrigation development was analysed for about 30% of the Anayari catchment, 100% of the Atankwidi and 30% of the Yarigatanga catchment. The image analysis for the Anayari catchment could be carried out on all the four years but for the Atankwidi and Yarigatanga catchments it could be carried out for 2005, 2007 and 2010. The information from interviews conducted and literature review are used for assessing the factors behind current trends and also for future trends in irrigation development in the study area. The literature review provides data on irrigation development in the area from the 1950s to 2010.

3. Results

3.1 Satellite Image Analysis of Irrigation Development

The satellite image analysis is intended to trace the irrigation footprints within the study area. The private-led irrigation systems are located along stream channels and flood plains where groundwater levels are high. Another location where there is expansion in private-led irrigation systems is downstream of the large-reservoir irrigation scheme. Farmers make use of return flows from the large-reservoir irrigation scheme for private irrigation farms. A consistent expansion of private-led irrigation systems is observed from the Google earth images from 2003 to 2010. The irrigation developments along the streams continue to expand over the years. However, there are some stream channels and flood plains where more irrigation can be developed but which currently remain untouched. The

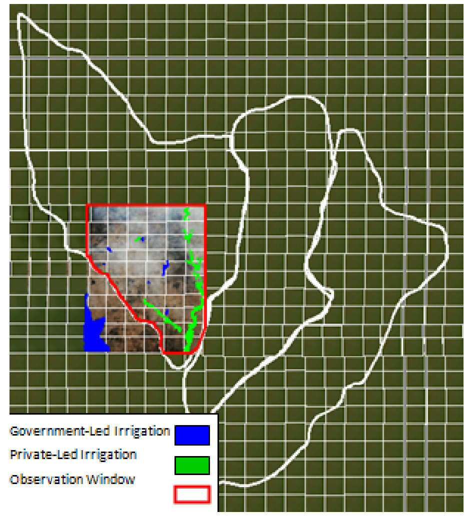

Figure 2. Irrigated areas in observed on 16-01-2003

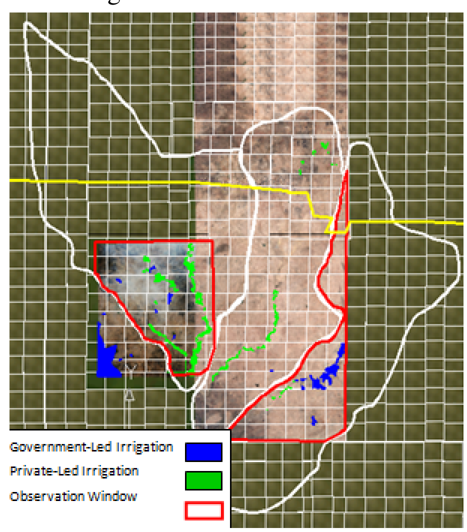

Figure 3. Irrigated areas in observed on 27-01-2005

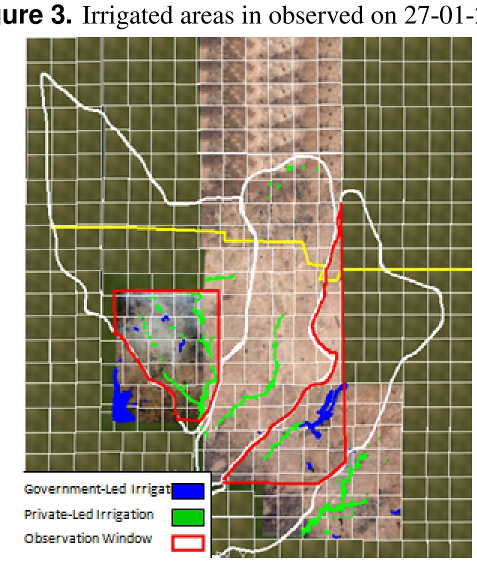

Figure 4. Irrigated areas in observed on 10-01-2007

observed irrigated areas for Anayari and Yarigatanga catchments are extrapolated to cover the total catchment area. The bases for extrapolation are from ground observations and data on irrigation developments. In the extrapolation, the irrigated area by small reservoirs in the satellite observation is considered to be proportional to the total catchment area. Private-led irrigation is more intense at the downstream portions of the catchment, as a result in the extrapolation; the intensity of private-led irrigation in the unobserved areas is estimated to be half of the actual.

3.2 Past Trend of Irrigation Development in the Study Area

An estimation of the general trend of irrigation development was carried out by combining results from the data analysis and the satellite image analysis. The trend analysis starts from 1950 when the development of small reservoirs for irrigation began in the study area. In this trend analysis, the developed irrigated areas are distinguished from the actual irrigated areas. This distinction is relevant for the government-led irrigation systems (Table 3). For example, the actually irrigated area in the Vea scheme fluctuates with time, as are the areas irrigated from the small reservoirs. The government started irrigation development from the 1950s with small reservoirs, followed by the development of the Vea scheme in 1980. Table 3 shows that irrigated areas in the government scheme have never reached the developed level. From the satellite image analysis an annual growth rate of 6.4%/a of private-led irrigation in the study area was observed from 2005-2010. Even though the government did not develop new schemes the irrigation activities within the existing schemes grew at an annual rate of 5.9% from 2005 to 2010. The average annual irrigation growth rate in the study area from 2005 to 2010 is 6.3%/a. The Private-led irrigation is 74% of the total irrigated area in the study area. Comparing this to the reported maximum rate of irrigation development (2.3%/a) across sub-Saharan Africa makes the growth in the White Volta sub-basin impressive [12].

Table 1. Estimated Irrigated Areas from Satellite Images

Catchment	Anayari Catchment (ha)		Atankwidi Catchment (ha)		Yarigatanga Catchment (ha)	
Observed Area (%)	30%		100%		30%	
Irrigation Type	Government-led Irrigation	Private-led Irrigation	Government-led Irrigation	Private-led Irrigation	Government-led Irrigation	Private-led Irrigation
2003	60	380	n/a	n/a	n/a	n/a
2005	65	420	2	191	153	20
2007	44	485	2	230	326	104
2010	40	483	2	224	355	155

n/a – not applicable

Table 2. Extrapolated irrigated areas from satellite images

Catchment	Anayari Catchment (ha)		Atankwidi Catchment (ha)		Yarigatanga Catchment (ha)	
Considered Area (%)	100%		100%		100%	
Irrigation Type	Government-led Irrigation	Private-led Irrigation	Government-led Irrigation	Private-led Irrigation	Government-led Irrigation	Private-led Irrigation
2003	200	760	n/a	n/a	n/a	n/a
2005	217	840	2	191	174	41
2007	147	970	2	230	348	208
2010	133	966	2	224	379	230

n/a – not applicable

Table 3. Government and Private-led irrigated areas in the study area

Year	Government-led Irrigation (ha)			Small Reservoirs Satellite Image {B}	Private-led Irrigation {C} (ha)	Total Irrigated Area{A+B+C} (ha)
	Developed Small & Large Reservoirs*	Vea irrigated areas ICOUR Records	Satellite Image {A}			
1950-1960	68	n/a	n/i	n/i	n/i	n/i
1961-1970	128	n/a	n/i	n/i	n/i	n/i
1971-1980	993	450	n/i	n/i	n/i	n/i
1981-1990	1017	404	n/i	n/i	n/i	n/i
1991-1995	1017	294	n/i	n/i	n/i	n/i
1996-2000	1017	331	n/i	n/i	n/i	n/i
2003	1017	377	n/i	n/i	n/i	n/i
2005	1017	111	145	248	1076	1469
2007	1017	340	312	185	1408	1905
2010	1017					

n/i – no image; * - obtained from records on irrigation development

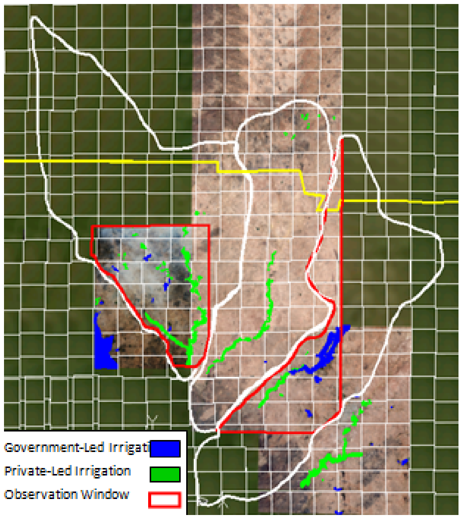

Figure 5. Irrigated areas in observed on 30-11-2010

4. Discussions

4.1 Factors Influencing Past Trend

This study shows that the contribution of private-led irrigation is significant in the study area. It is therefore important to give much needed attention to private led (also known as informal) irrigation development in all parts of sub-Saharan Africa. The potential for the upscaling of private-led irrigation is high and thus factors influencing the past trend are worth investigating. Findings can help inform policy making in support of irrigation development. The study identifies the following factors as having influenced the past trend of irrigation development. The factors identified are: (1) rising demand for vegetable products in the urban centres of southern Ghana, (2) challenges farmers had with existing government-led irrigation systems, (3) availability of appropriate irrigation technologies, (4) favourable land-tenure system, and (5) availability of cheap labour and farm inputs. These factors are discussed as follows.

Market for Vegetables

The major contributor to the expansion of irrigation in the study area is the rising demand for vegetable products in the urban centres of southern Ghana. The increasing rate of urbanisation in Ghana, coupled with increasing population has both contributed to the increasing demand for vegetables. The production season of the Upper East Region is within the dry-season therefore requiring irrigation for vegetable production. Apart from tomato production, the Upper East Region and countries such as Burkina Faso and Mali are the main sources of supply of onions for the urban centres of Ghana.

Challenges associated with Government-led Irrigation systems

For a very long time the government had been the main investor in irrigation infrastructure in the study area. The management of these schemes are centralised and managed by government agencies. The large-scale irrigation scheme had unresolved land-tenure problems which denied local farmers access [10]. Also the rigid control of irrigation water supply by the management of the large-reservoir irrigation schemes did not necessarily conform to specific farmer demands.

Availability of appropriate irrigation technologies

The most prevalent of these technologies is the rope and bucket. This technology aided them in harnessing shallow groundwater for irrigation. The advantages of using this technology are that it is cheap, locally available and does not need skill in its application. Also the availability of motorized pumps on the local market encouraged farmers to explore the options of riverine pump irrigation.

Favourable land-tenure system

The existing land-tenure arrangement in the study area enables the youth to hire land on temporal basis for dry-season irrigation. This also enables women who don't own land in the study area to access land for dry-season irrigation.

Availability of labour, energy, farm inputs and credits

The availability of some important factors of production has also enabled the emergence of these new irrigation technologies in the study area. All of the available technologies require the use of labour and/or energy to apply water to irrigation plots. Fortunately there is abundant labour available for such activities during the January-April season. Farmers have significantly depended on such labour for the development of these irrigation technologies. In the study area, access to these inputs is good as well as the servicing of farm equipment, which is provided by the private sector. Irrigation farmers in the study area thus have access to sufficient labour, fuel for motorized pumps, chemicals, fertilizer, seeds and servicing of farm equipments. The ability of some farmer groups to access credits from banks, relatives and friends has also contributed to the current trend of irrigation development in the study area.

4.2 Drivers for the Upscaling of Irrigation Development

The potential of future irrigation development is analysed on the following factors: historical trend, irrigation potential, possible future interventions (policies, investments and technology), and emerging issues (economy, markets and entrepreneurship) [9];[4];[6]. Literature has shown that several drivers led to the large public investments in irrigation in the second half of the 20th century. The drivers include global efforts (external drivers) to increase staple food production, ensure food self-sufficiency and avoid famine [4];[2]. Similarly there are drivers that are likely to influence the future expansion of irrigation in sub-Saharan Africa which need to be identified and utilized. Researchers still see that there are reasons why investment in irrigation should continue to increase. Some of the reasons identified in the literature are that: (1) irrigation is a pathway for poverty reduction; (2) irrigation is needed for the changing food preferences and changing social priorities; (3) to preserve and modernize the present stock of irrigation; (4) increase in competing water uses demand improving irrigation productivity; and (5) need to respond to climate change impacts [4];[1];[6];[8]. Using the above listed reasons for continued investment and the past trend as a backdrop, the study summarises the potential drivers likely to influence future trend of irrigation in the study area as: (1) expansion of output market for irrigated products; (2) appropriate and affordable irrigation technologies; (3) government policies and interventions (infrastructure, subsidies, poverty reduction strategies, climate adaptation measures, emerging trends of irrigation management, etc); and (4) reliable farmer support environment. Few studies on irrigation potential have been conducted in the study area. The first study was conducted by the Water Research Institute of Ghana as part of the Water Resources Management Study of the Volta Basin. In this study the irrigation potential of the White Volta sub-basin of Ghana was estimated as 314,000ha (6% of the catchment area) [11]. Comparing the potential with the developed area implies that over 80% of the potential irrigable area is still undeveloped. Thus there is high opportunity to upscale irrigation in the study area.

5. conclusion

The satellite image analysis showed that private-led irrigation systems experienced an annual growth rate of 6.4% whiles the developed government-led irrigation schemes expanded cultivated areas at annual rate of 5.9% from 2005 to 2010. The study area experienced an overall annual irrigation growth rate of 6.3%. Private-led irrigation represents about 74% of total irrigation in the study area. The challenges associated with government-led irrigation systems, the advent of appropriate irrigation technologies, a favourable land-tenure system and an enabling local support environment, which include labour, technical services and farm inputs on the local market, all played major roles in achieving the annual growth. So far, the full potential of developed government-led irrigation systems has not been realised. The factors that have influenced the past trend are likely to sustain the current state of irrigation in the basin. However additional factors are likely to increase irrigation development beyond the current growth rate in the near future. The additional factors include, expanding markets for irrigated products, introduction of new irrigation technologies, government policies and interventions and emerging trends of irrigation management. Advantage must be taken of these opportunities to upscale irrigation development in the basin knowing that more than 80% of the irrigation potential in the basin remains untapped, and that there seem to be sufficient water resources available to fully support this potential. The implications of the future trend should however not be overlooked. This is because the upscaling of irrigation in the basin has direct impact on the competing water uses, downstream water uses and the environment. Also the possible implications of climate change on water availability should not be forgotten. There is therefore the need to investigate the possible impact of the upscaling of irrigation development on other competing water uses.

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