Flood Based Irrigation in the White Volta Sub Basin: Status and Potential

14

Overview Paper Spate Irrigation

Spate Irrigation Network

1. Water management in the Nakambe

Spate and flood water irrigation techniques are integral part of households situated in the flood plains of the large 400,000 km^2 Volta River Basin. Its main rivers - known as White Volta (Nakambe), Black Volta (Mouhoun) and Oti - start in northern Burkina Faso and flow south to end up in the world's largest artificial lake of the Akosombo Dam. In this paper particularly the water management practices of the White Volta sub basin will be discussed, due to its central location. The 55,539 km^2 of the upper catchment is located in Burkina Faso, while the 49,210 km^2 downstream part of the catchment is located in Ghana. Its central location in the larger Volta River Basin is presented in figure 1.

The White Volta is being fed by run-off from a single raining season lasting from May till October. Rainfall in the upper catchment, being part of the Sudano-Sahelian Climate Zone, ranges from 600 to 900 mm; while rainfall in the southern catchment is 900-1200 mm, being part of the wetter Sudan climate zone. In the Sudano-Sahelian zone, located between 11o 30' and 14o N, the rainy season – with on average 43 rainy days, lasts 4 to 5 months. The southern part of the Sudan zone, located south of 11o 30'N latitude, has on average 74 rainy days in 6 to 7 months.

Figure 1: Sub catchments of the Black and White Volta and the Oti River (Source: Amisigo et al. 2008)

River	Runoff Coefficient*	Runoff Coefficient**
Black Volta	4.9	8.3
White Volta	7.5	10.8
Oti River	13.5	14.8
Lower Main Volta	Not stated	17

Table 1: Runoff Coefficients of Volta River (*Source: van de Giesen et al. 2001; **Source: Barry et al. 2005)

The rainfall peak is often in August with short intensive showers, often resulting in floods. Average annual run-off coefficients in the White Volta Basin are between 7.5 and 11% (van de Giesen et al. 2001 and Barry et al. 2005).

Using these surface run-off volumes a total 155,809 hectares could be irrigated (Barry et al. 2005). One third of this irrigation area would be situated in the upstream part (Burkina Faso) and two-third in the downstream part (Ghana)(FAO, 1997). In 2011, the total equipped area for irrigation and irrigated area were respectively estimated on 3,391 and 1,929 hectares (Ofosu, 2011). These figures show that there is still enormous room for enlarging agricultural output by irrigation. However, watershed planning, including land use planning and location of water harvesting methods, should be in close correspondence with climate change models. As presented in Minia (1998), simulations of run-off using GCM-based climate scenarios indicate that, run-off is expected to decrease between 16 and 37 % over the period 2020-2050 (Opoku-Ankomah, 2000; In: Barry et al. 2005: pp. 22). However, according to a study by the Water Resources Commission of Ghana to assess and forecast the flood hazards in the White Volta River, it is estimated that, spilling from the Bagre Dam in Burkina Faso would add up between 20 cm to 75 cm to the maximum flood level along the White Volta River (see Figure 2), increasing flood frequency. Two major flood scenarios were identified in the White Volta Basin, mainly floods returning every 2-5 years and those returning every 10-100 years (See Figure 3). Justified questions in this context are: What would be the impact of this on the current planning or irrigation techniques? Which techniques should be promoted and which not?

Flood based farming and spate irrigation techniques come first to mind to assist farmers and water management authorities adapting to changing run-off patterns of the White Volta.

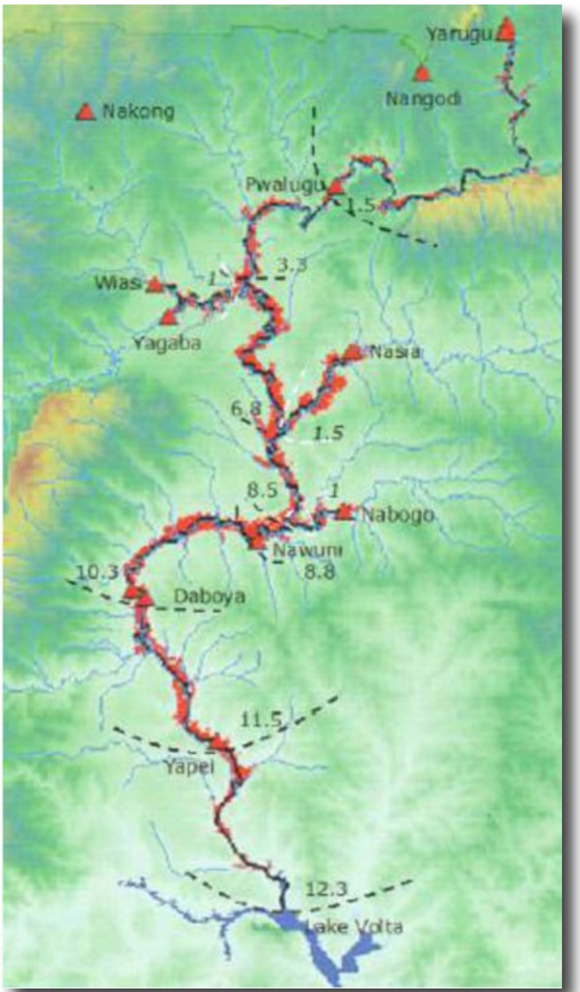

Figure 2: Flood Propagation along the White Volta River from Yarugu to Lake Volta. The areas in red show frequently flooded areas along the River (Source: White Volta Flood Assessment and Forecasting Report, 2012)

Under Spate Irrigation, short duration floods - typical for semi-arid environments - are diverted from river beds and spread over land - to cultivate crops, feed drinking water ponds and irrigate pasture areas or forest land. The current reservoir storage in the Burkina Faso section of the White Volta Basin is about 4,300 MCM. Optimizing the use of this technique in the Ghana Section of the White Volta Basin could store a total of 8,180 MCM in flood filled reservoirs per season (Barry et al. 2005), satisfying three times the irrigation demand of the potential irrigable area[1]. The relative gentle sloped White Volta catchment (60-530 m.a.s.l.) makes it ultimately suitable for controlled water diversion from river beds to storage sites. Currently there are some 1,050 small reservoirs constructed in the White Volta Basin; with over 850 in the upper watershed

Figure 3: Flood Risk Map for the White Volta at Yagaba (see Figure 2 for position of Yagaba). Light blue are aeas with very high flood risk and inundated on average every other year, while in dark blue those areas are affected in the event of major floods (every 10 to 100 years) (Source: White Volta Flood Assessment and Forecasting Report, 2012)

(Ghana) and 200 in the downstream watershed (Burkina Faso) (Cecchi et al. 2009; and Boelee et al. 2009). As the characteristics of the White Volta Basin are similar to those of semi-arid environments - having a single rainfall season with floods – the spate irrigation potential is large in this area.

2. Flood Based Irrigation in the White Volta Basin

As mentioned, flood based irrigation practices are already widely integrated in households situated in the White Volta Basin. The different methods, as well as land and water resources are specified below.

2.1 Land Sources

Soil types differ for the predominant reliefs and erosion sensitivity. The major soil types in the White Volta are shown in Table 2.

In general, the population in the Volta Basin heavily depends on the land resources of the region for agriculture and livestock breeding. The increasing demographic pressures have resulted in over and misusing land resources (e.g. Barry et al. 2005; Andah and Gichuki, 2005). Soil degradation, erosion, and desertification processes manifest themselves in low agricultural

1) *Assuming an average water demand per hectare of 14,000* m^3 *per growing season: 7,000* m^3 *for the crop water demand and 7,000* m^3 *assuming an irrigation efficiency of 50%.*

Soil Group	Predominant Relief	Predominant Texture	Erosion Hazard
Savannah Ochrosols	Upper and Middle Slopes, Gently	Moderately, Heavy to light	Moderate Sheet and Gully Erosion
Groundwater Water Laterites	Near level to level, lower slopes to valley bottoms	Light overconcentrations and Iron pan	Severe to very severe sheet erosion
Savannah Ochrosols Integrades	Gently Undulating to level middle to lower Slopes	Medium to light	Moderate to severe sheet erosion

Table 2: Soil Types and Erosion Hazards in the White Volta sub-Basin (Source: Barry et al. 2005)

productivity, destructing soil's natural productive capacity, compacting soil, degrading water quality, and loss or reduction of vegetation cover. Furthermore, the increased mobility of sediments also affects reservoir capacities and their lifespan. A study conducted by Adwubi et al. (2009) indicate annual sedimentation rates of 1,272; 3,518; 2,764 and 6,135 t/yr for Doba, Dua, Zebilla and Kumpalgogo reservoir.

The land tenure system of the White Volta in Burkina Faso is based on the RAF- legislation (Réform Agraire et Foncière) and the decentralization policy (de Zeeuw, 1997). However, the distribution of land rights is based on the socio-political system (the political history of the village and region from which the alliances and hierarchical relationships between lineages are derived) and on family relationships (access to land and resources depending on one's social status within the family), so that social networks govern access rights (Berry, 1993). In Ghana a plurality of land tenure and management systems (i.e. state/public and customary) prevails (Kasanga and Kotey, 2001). Land ownership within the basin is basically traditionally organized. The local customary authority overlooking land issues in Northern Ghana is the tendana, the traditional earth priest. Local farmers have "family land", which they do not own in a legal way and cannot sell it, but they do have secure usufruct rights to this land, which can be inherited within the family (Birner et al. 2005). Some other areas are demarcated for control by the government agencies, such as the Volta River Authority, forest reserves and wildlife & National Parks.

2.2 Water Sources

Rainfall in the Volta Basin averages 1,025 mm/yr of which 9%, or 36 km^3, becomes river flow. Rainfall variability within a rainy season is very large due to the convective nature of most rainstorms. The onset of the rainy season is especially unpredictable.

From an agronomic point of view, rainfall in the region can only be characterized as unreliable (van de Giesen et al. 2001).

The first intermittent flows in the Nakambe occur in May. They become permanent flows in July, August and September (Barry et al. 2005: pp. 74). In van de Giesen et al. (2001) it was shown that in the Volta Basin, riverflow varies much more from year to year than rainfall with coefficients of variation of 57% and 7%, respectively. Main reason for this is that the water storage capacity of the White Volta Basin is around 343 km^3 and that access rainfall will run-off. The calculated correlation between yearly rainfall (P) and riverflow (Q) found by van Giesen et al. (2001) is:

$$Q = 0.529(P - 343)\ [km^3/year] \quad \text{(Eq. 1)}$$

with a regression coefficient r = 0.89.

The threshold demonstrates the high sensitivity of riverflow to rainfall: relatively small changes in yearly rainfall cause large changes in riverflow. This indicates that only small changes in rainfall could have dramatic effects on run-off rates. Although rainfall decreased by only 5% from 1936 to 1998, run-off decreased by 14% (Andreini, 2000).

The runoff/rainfall sensitivity also implies sensitivity with respect to the mechanisms that divide rainfall between evapotranspiration and runoff (van de Giesen et al. 2001).Simulations of run-off using GCM-based climate scenarios developed by Minia (1998) showed 15.8% and 37% reduction in run-off of the White Volta Basin for years 2020 and 2050, respectively (Opoku-Ankomah, 2000).

The average annual runoff from the White Volta is about 272 m^3/s and the mean monthly runoff from within the basin varies from a maximum annual flow of 1,216 m^3/s to a minimum of about 0.11 m^3/s.

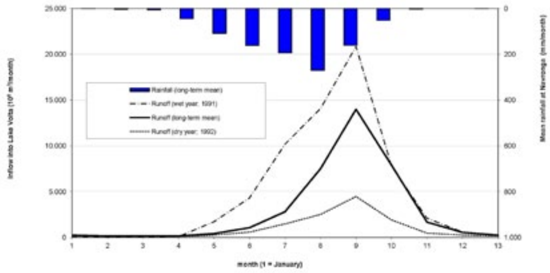

Figure 4: Hydrograph of the Volta River and Rainfall at Navrongo (Data source: Obeng-Asiedu, 2004)

Potential storage sites have been identified within the basin totalling nearly 8180 MCM which could regulate the basin yield at a minimum annual flow of about 209 m^3/s (Barry et al. 2005: pp. 69).

Specific suspended sediment yield in this basin is between 8.5 and $14.0t/yr/km^2$. Current surface water uses in the basin are estimated at about $0.11m^3/s$ for domestic water supply and about 2 m^3/s at numerous small irrigation projects (Barry et al. 2005: pp. 69). This shows there is still enormous potential to harvest more water or beneficial agricultural uses.

2.3 Irrigation Technologies

The White Volta sub-basin is characterized with several irrigation technologies being conventional as well as indigenous. Below follows a brief description of the irrigation technologies found in the White Volta sub-Basin including the crop types, yield and area coverage. The choice of irrigation technology is influenced by the source of water, access to land and the financial strength of the farmer.

Small Reservoirs

Small reservoirs are impoundments with dam walls up to 15 m in height or storage capacities of less than three MCM of water (ICID, 2000). They are used in the White Volta sub-basin for the provision of water mainly for irrigation (<100ha), for livestock watering, fishing/aquaculture, construction and domestic use (van de Giesen, 2006).

There are over 2,000 small reservoirs in Burkina Faso (ICOLD, 2001). In the Upper East Region of Ghana which falls in the White Volta sub-basin, there are 156 small reservoirs in (IFAD, 2005). In the White Volta Basin itself there are some 1,050 small reservoirs. The average size of land irrigated by a small reservoir is about 8.5 ha for producing vegetables, mainly onions, tomatoes, pepper and leafy vegetables (Birner et al., 2005). According to Ofosu et al. (2010) Small Reservoir Irrigation used in cultivating tomatoes had an average yield of 20 ton/ha in 2008. The capital cost of developing a small reservoir averages 33,000 US$/ha and the maintenance cost is about 100 US/ha/yr. Farmers using small reservoirs to cultivate tomatoes spend about 47 US$/ha for irrigating their farms (Ofosu et al. 2010).

Dugouts

Dugouts are fundamentally excavations positioned within the flood plains of rivers and streams (Ofori et. al., 2006). Dugouts are constructed to receive surface water runoff through diversion channels from the streams during the rainy season and store the water for livestock farming, aquaculture, irrigation and domestic water use during the dry season. Crops mainly produced under this technology are tomato and pepper. However, the yield of crops cultivated under this technology are similar to that of small reservoirs.

The capital cost of developing a dugouts averages 6,500 US$/ha and the maintenance cost is about 150 US/ha/yr. Farmers using small reservoirs to cultivate tomatoes spend about 400 US$/ha for irrigating their farms (Ofosu et al. 2010).

Permanent Shallow Wells

The permanent shallow well irrigation technology is one of the oldest irrigation technologies practised in the White Volta sub-basin. The number of permanent shallow wells in the White Volta sub-basin even though not counted would be about 30 times the number of small reservoirs. This estimate is based on the average number of permanent shallow wells in an area with a single small reservoir. It occurs both in the up- and downstream parts of the White Volta sub-Basin. It is used mainly for the cultivation of tomatoes, pepper, carrots, cabbage and sweet potatoes. The average plot size of a permanent shallow well farm is about 500 square meter.

Studies conducted by Ofosu et al. (2010) shows that the average yield of tomatoes cultivated under permanent shallow wells is high, about 60 t/ha. This figure is thrice as high as tomato yield from small reservoirs and dug-outs. the reasons for the difference in yield as stated by Ofosu et al. (2010) are due to the difference in fertilizer application by farmers, coupled with the fact that the using groundwater source and applying the water manually and directly at the root zone of the crops increases yield.

Box 1: The Four Brothers of Atankwidi

The alluvial dugouts were accidentally introduced in 1995 by four brothers in the Atankwidi catchment of the White Volta sub-basin during the construction of the Navrongo-Bolgatanga Road. Road embankments led to water storage during the dry season in the Atankwidi Stream which is non-perennial. The water storage attracted a young man by name Joel who happened to be a landowner along the Atankwidi Stream and also used to be an irrigation farmer in Kumasi (second largest city in Ghana) to use the stored water for irrigation. The following year he was joined by three of his brothers who were also landowners along the stream. They continued in subsequent years with other community members joining. However after the road construction they started experiencing water shortages as the irrigation progressed due to increased abstraction forcing the farmers to scoop the soil in the river bed in search of water. The scooping results in irregularly shaped alluvial dugouts in the river bed. The alluvial dugouts are fed by groundwater recharge. A field count made during the 2007/2008 dry season within a stretch of about 30km along the Atankwidi River showed that there were about 705 farmers using the riverine alluvial dugout technology on both sides of the river. Thus the entrepreneurship skills acquired from Kumasi helped Joel to exploit the water resource, and ended up creating a technology which did not exist in the area before.

The capital cost of developing a permanent shallow well averages 4800 US$/ha and the maintenance cost is about 400 US$/ha/yr. Farmers using small reservoirs to cultivate tomatoes. They fetch the water at no cost in terms of fuel or pump hiring (Ofosu et al. 2010).

Riverine Pump Systems

Over the years farmers have been farming along the banks of the White Volta by pumping water directly from the river. This technology has been practised in the sub-basin since 1992 around Pwalugu in the Upper East Region and has expanded over the years.

Other farmers also locate their farms downstream of large irrigation schemes such as Vea and Tono and use the return flows and excess water from these schemes. The main crops cultivated under this irrigation system are tomatoes and pepper. According to studies conducted by Ofosu et al (2010) the yield of riverine pump system is about 15 t/ha. The farm sizes range from 0.4 ha to 6 ha especially with tomato farms.

Downstream of the Vea irrigation scheme there about 50 farmers using petrol pumps and about 5 farmers using diesel pumps. The figures are about double for the Tono scheme. Along the White Volta at Pwalugu, the farmers are commercial farmers numbering over 100 who mostly use diesel pumps.

The capital cost in Riverine Pump Irrigation includes the pump and pipes or water hose which on the average is about 1,700 US$ for diesel pumps and about 700 US$ for petrol pumps. The maintenance cost is about 50 US$/yr. Farmers using pumps to cultivate tomatoes spend about 400 US$/ha/yr on fuel for irrigation (Ofosu et al. 2010).

Temporal Shallow Wells

The use of temporal shallow wells is one of the new irrigation technologies that have emerged in the sub-basin within the past two decades. It is common in the Upper East Region, specifically in the Atankwidi and Anayari sub-catchments where groundwater levels range between 3-8 m throughout the dry season. Temporal shallow wells tend to be used in cases where the irrigation farmer rents the land from the landowner for just the dry season. The farmers refill the wells with soil at the end of the dry season. This explains why the wells are temporal.

The capital cost of developing a temporal shallow well averages 1200 US$/ha with no maintenance cost and water abstraction cost. The farmer is responsible for the cost in developing the temporal wells (Ofosu et al. 2010).

This technology is used in cultivating crops such as tomato, okra and pepper. The average plot size of a farm under this system is about 500 m^2. The tomato yield of temporal shallow wells is about 60 t/ha.

Riverine Alluvial Dugouts

Riverine Alluvial dugouts are practised mainly in non-perennial streams in the sub-basin. This technology is mainly common along the Atankwidi and Anayari Rivers both in the Upper East Region of Ghana. The average farm size in this system is about 0.2 ha. The crops mainly produced under this technology is Tomatoes and Chilli Pepper. According to studies conducted by Ofosu et al (2010) the yield of riverine pump system for tomatoes is about 40 t/ha.

The capital cost in Riverine Alluvial Dugouts includes the cost of digging which is seasonal and cost of petrol pump/water hose. On the average the digging cost 525 US$ and petrol pump with water hose cost 700 US$. The pump maintenance cost is about 50 US$/yr. The farmers spend about 755 US$/ha/yr on fuel for irrigation (Ofosu et al. 2010).

Figure 5: Alluvial Dugout under construction

2.4 Strenghts and weaknesses

A summary of the strengths and weaknesses of the irrigation technologies in the White Volta sub-basin are presented below.

Irrigation Technologies	Strengths	Weaknesses
Riverine Alluvial Dugouts	1) Farmers using this technology recorded very good yield and high water productivity for tomatoes in 2008.	1) Because of the competition for water farmers using this technology are compelled to start irrigation around the same period, any lateness results in higher expenditure on water.
	2) The relative small farm plot makes the technology manageable by the poor-local farmer financially.	2) Farmers using this technology spend a lot on water because of the digging. The amount of money spent on water is twice that of riverine water irrigation.
	3) About $1000/ha is spent on labour under this technology which goes to non-farmers as poverty reduction.	3) The technology contributes to siltation of the streams and rivers since the farmers do not observe the 100m buffer along the river channel.
	4) The hiring of lands for temporal shallow wells makes the technology open to all farmers both landowners and non-landowners and all gender.	4) The technology has low women participation because of the financial constraints and amount of labour work involved.
	5) The existing land rights and communal relationship in the sub-basin favours the spread of the technology.	5) This technology can only be practised along stream/river channels thereby restricting its upscaling and beneficiaries.
	6) The organisation of farmers using this technology has helped to negotiate good market prices for their products.	

Irrigation Technologies	Strengths	Weaknesses
Small Reservoirs	1) Have formalised community ownership which gives equal access to land and water irrespective of gender.	1) There is lack of technical advice on the water management of small reservoirs.
	2) Favourable water application methods thus attracts more women participation	2) The initial investment cost is expensive compared to other irrigation technologies.
	3) Farmers are in full control of the management of the irrigation facility and are able to handle minor repairs and also maintain the facility	3) Even though it is managed by the community, the community is not in the financial position to handle major repairs unless the government or a donor agency intervenes.
	4) Water User Associations (WUAs) are recognised by the Ministry of Food and Agriculture (MOFA) and thus receive extension services from MOFA especialy on agronomy.	4) The development of small reservoirs has varying degrees of environmental impact problems to address and land-tenure issues to resolve.
	5) Small reservoirs provide small-scale employment for farmers in the dry season (average of 7 farmers per hectare).	5) The multiple water-use of the small reservoir which gives priority to other uses over irrigation also contributes the water shortage in irrigation.
	6) Farmers using small reservoirs spend relatively less expenditure on water for irrigation except for those who use pumps for water abstraction and application.	6) Some crops which have long growing periods such as pepper cannot be cultivated under some small reservoirs where the capacity cannot support the demand.
	7) Small reservoirs consume the least amount of water for irrigation but are sometimes inadequate for the crops.	7) Individual farmers do not have control over their watering schedule and are sometimes affected when they miss the opportunity to water.
	8) Due to the small sizes of farm plots, poor farmers are able to afford adequate fertilizer and chemicals for their crops to improve their yield.	8) Due to the low labour employment in small reservoirs, the technology gives less income to non-farmers in the community in the form of labour.
	9) Small reservoirs close to major roads and community centres have access to good markets for their products due to market proximity.	9) Has comparatively low water productivity.
	10) Small reservoirs located close to community centres can produce a variety of local vegetables which they sell on the local market	
	11) Due to the small farm plots a farmer can easily manage the farm without spending on labour thereby reducing expenditure for the farmer.	

Irrigation Technologies	Strengths	Weaknesses
Permanent Shallow Wells	1) Due to the small sizes of farm plots, poor farmers are able to afford adequate fertilizer and chemicals for their crops. This accounts for the high yields achieved in permanent shallow well farmers.	1) Due to the water lifting technology employed by the farmers which is highly labour intensive, farmers are restricted from expanding their farm plots beyond certain limits beyond their single ability to irrigate. This therefore makes it difficult for a farmer to increase productivity and income by expanding the farm plot.
	2) It has high relatively high water productivity.	2) Permanent shallow wells are only practical in areas of high groundwater table.
	3) There is no seasonal recurrent investment cost in infrastructure such as the temporal shallow wells except in maintaining the wells.	3) The land tenure system in the sub-basin disadvantages women's access to land. This accounts for the low women participation. Women in this technology mostly do it on their husbands' land.
	4) The total investment cost in permanent shallow wells is about one-sixth that of small reservoirs and can be easily be developed by local farmers as well as government and development agencies.	4) Permanent shallow wells only favour landowners because of the construction of the permanent infrastructure. Landownership therefore hampers the upscaling of this technology.
	5) The permanent shallow wells can be used to cultivate crops with longer growth period so far as groundwater is reliable during the dry season.	5) Farmers using permanent shallow wells over-use fertilizers and chemicals due to their relatively small farm sizes and this can lead to water pollution.
	6) Farmers using permanent shallow wells are able to do multiple crops in succession during the dry season without water scarcity. Farmers in Burkina Faso using this technology farm all-year round.	6) Poor farmers find it difficult to raise the initial capital to invest in lining their wells, this leads to caving in and siltation of wells, thus increases the labour cost as they have to repair their wells every dry season.
	7) Permanent shallow wells have low operating cost due to low cost of labour and no expenditure in water abstraction.	7) Members of the community who are non-farmers receive less income in the form of labour.
	8) Permanent shallow wells employ the highest number of farmers per one hectare (average of 33 farmers) of land thereby providing a lot of employment in the dry season.	8) Permanent shallow well farmers who produced tomatoes realised the least profits compared to other technologies. This can be attributed to the nature of the market for tomatoes which does not favour dispersed farms. Farmers in such situations send their tomatoes to the local market where prices are relatively low.
	9) The income of farmers using permanent shallow well can be improved if they concentrate on vegetables of high demand but low supply such as pepper.	

Irrigation Technologies	Strengths	Weaknesses
Large Reservoirs	1) There is regular water schedule and constant water supply for farmers using large irrigation schemes.	1) The water-use efficiency of the large reservoirs is poor (about 50%) and can be attributed to lack of proper management of facilities.
	2) Farmers using large reservoirs receive adequate amounts of water needed for irrigation.	2) Large reservoirs in the sub-basin have the least water productivity with respect to tomato production compared to other irrigation technologies.
	3) Farmers using large irrigation schemes spend less on water in the absence of energy consumption.	3) The management is unable to carry out major repairs on the facility to ensure efficiency.
	4) Rice-farmers have a ready market for their products. The rice is bought by the scheme's management	4) The management has difficulty collecting water levies from farmers due to broken water-control systems thereby running at a loss every season.
	5) The large reservoir scheme produces good yield of rice.	5) Farmers in the large irrigation schemes realised the least profits in tomatoes production due to poor yields.
	6) There is also more women participation in rice cultivation due to the relatively small farm sizes which are manageable by the poor local women.	6) The development of large-reservoir irrigation scheme has high environmental and social impact.
	7) There are formalised land arrangements between the farmers and the management which favour both genders.	7) The productivity of large irrigation schemes is low. It has the lowest yield in tomatoes production compared to other technologies.
	8) Due to the low usage of fertilizer and chemicals in large reservoir irrigation schemes their contribution to water pollution is minimal.	8) The financial gains made out of the investment 20 years ago by the government are yet to be realised since the management is still subsidised by government.
	9) Farmers producing vegetables in large irrigation schemes spend about 50% of their operating cost on labour which is income to the non-irrigators in the community.	9) In the absence of any financial assistance for farmers, the relative large farm sizes of the large irrigation scheme seems to be too expensive for the poor local farmers.
		10) Fewer women participate in vegetable cultivation due to financial constraints.
		11) The large irrigation scheme provides the least job opportunities for farmers in the dry-season having an average of 2 farmers per hectare for vegetable cultivation.
		12) The management is unable to find market for the perishable commodities such as tomatoes produced by farmers in the large scheme.
		13) Farmers in large-irrigation schemes do not have control over water and therefore are unable to set their own target markets for vegetable crops.

Irrigation Technologies	Strengths	Weaknesses
Riverine Water Irrigation	1) Farmers using riverine water control their watering schedule and also have target market options (early, normal or late markets).	1) Farmers using riverine water who disobey the 100m reservation belt contribute to siltation of the streams and rivers.
	2) There is no digging cost associated with riverine water as compared to riverine alluvial dugouts. The expenditure on water is about half that of the alluvial dugouts.	2) The farm plots are relatively large and farmers use low quantities of fertilizer which affects their yield.
	3) Riverine water technology makes use of the excess water that leaves large irrigation thereby increasing the productivity of the large irrigation scheme.	3) The water productivity of riverine water technology is low due to the low yields.
	4) Fertilizer application among riverine water farmers is minimal and therefore has minimal water pollution compared to other technologies.	4) The initial investment in pumps and pipes is expensive and not feasible for poor farmers.
	5) Farmers can do double cropping in the dry season due to the adequate water in perennial rivers/streams and downstream of large irrigation schemes.	5) It employs about two farmers per hectare which has a low impact on the farmer population.
	6) This technology can easily be developed and maintained by the local individuals without government assistance	6) The expenditure on water is high due to energy consumption used in water abstraction.
		7) It has low women participation due to existing land tenure system and capital intensive nature which poor local women cannot afford.

Irrigation Technologies	Strengths	Weaknesses
Temporal Shallow Wells	1) Farmers using temporal shallow wells recorded the highest yield of tomatoes in 2008 compared to other technologies.	1) The inability to make the wells permanent is a major setback for the technology.
	2) The relative small farm plot makes the technology manageable by the poor-local farmer financially.	2) There is high competition for groundwater in the later stages of the season which increases the expenditure of farmers by digging deeper to hunt for groundwater.
	3) It has high water productivity.	3) The technology is limited to areas of high groundwater table.
	4) The technology employs a good number of farmers per hectare (20 farmers per hectare) and also provided good income (average of $420 per farmer in 2008) at the end of the season in tomato production.	4) Due to the small farm plots farmers are able to afford fertilizer and chemicals in excess of what is needed and collectively contribute to water pollution in the sub-basin.
	5) The technology also spends about $2000/ha on labour which goes to non-farmers as income in the dry season thereby contributing to poverty reduction.	5) Also farmers are limited in expanding the farm plots because of the prevailing water lifting mechanism which is labour-intensive and hiring of labour will increase expenditure.
	6) The hiring of land for temporal shallow wells makes the technology open to all farmers both landowners and non-landowners and all gender. This is one of the reasons why women participation in this technology is relatively high.	6) The technology is amongst the highest water users, which may be due to lack of knowledge on crop water demand by the farmers.
	7) The existing land rights and communal relationship in the sub-basin favours the spread of the technology.	7) Women who use the technology spend more on digging cost than men since they are unable to dig the wells themselves.
	8) The clustering of temporal shallow well farms makes them attract market women for their products since they can meet all their demand.	8) Because of the competition for water farmers using this technology are compelled to start irrigation around the same period, any late-comer will be found wanting. This is because the late farmer will meet a lower groundwater level due to consistent drop in the groundwater level throughout the season and thus will be more disadvantaged.
	9) The up-scaling of this technology does not require the financial support from government since it is affordable by the private farmer.	

2.5 Socio-economic impact

Investment in infrastructure and equipment for irrigation is either by government, development agency or private individual or group of individuals. In the White Volta sub-basin governments and development agencies invest in the development of large reservoir irrigation schemes and small reservoirs, while other technologies in the sub-basin are developed by private individuals or farmer groups. Table 3 summarizes the investment cost and seasonal expenditure on water (abstraction and distribution) incurred on the various irrigation technologies for tomato cultivation (Ofosu 2011).

Large reservoir irrigation farmer has the lowest profit margin amongst all the irrigation technologies. The temporal and permanent shallow wells have the highest profit margins making the two technologies the most economically viable irrigation technologies (see figure 5). Interestingly, despite the relatively large farm plots of the large reservoir irrigation scheme, the profit made per farmer is almost equal to that of the temporal shallow well farmers (Ofosu 2011)

The average profits for the season were for small reservoirs 420 US$/farmer, permanent shallow wells 225 US$/farmer, large reservoir irrigation 470 US$/farmer, riverine water 1,050 US$/farmer, temporal shallow wells 420 US$/farmer and riverine alluvial dugouts 620 US$/farmer. Thus unless the productivity of the large irrigation scheme is improved the users are not better off than those using more expensive technologies on comparatively smaller plots (Ofosu 2011).

The operational costs spent on labour hired from the inhabitants of the sub-basin during the irrigation season helps reduce poverty in the sub-basin. The irrigators employ basically the youth and women. Typically, the youth are hired as farm assistants by farmers using riverine water, large irrigation schemes and the riverine alluvial dugouts. Also the youth are hired for land preparation, transplanting, weeding, digging and

Irrigation technology	Investment cost ($/ha)	Lifespan (years)	Depreciation cost ($/ha/yr)	Maintenance cost ($/ha/yr)	Water-use cost ($/ha/yr)	Total cost ($/ha/yr)	Seasonal Expenditure ($/ha/yr)
Upper East Region							
Small Reservoir	33,000	25	4,650	100	47	4,797	47
Permanent Shallow Well	4,800	30	672	400	0	1,072	400
Large Reservoir	15,000	50	2,029	150	57	2236	57
Riverine water	1,700 [a]	8	360	50	550	960	600
Temporal Shallow Well	1,200	0,5	1,200	0	0	1,200	1,200
Riverine Alluvial Dugout	700 [a] 525 [b]	5 0.5	200 525	50	755	1,530	1,330
Burkina Faso							
Small Reservoir	38,000	25	2,500	100	80	2,680	80
Permanent Shallow Well	6,500	30	385	600	0	985	600

[a] = Petrol, pump and pipes
[b] = Constructing the dugout

Table3: Cost of water-use for irrigation technologies in Upper East Region and Burkina Faso.

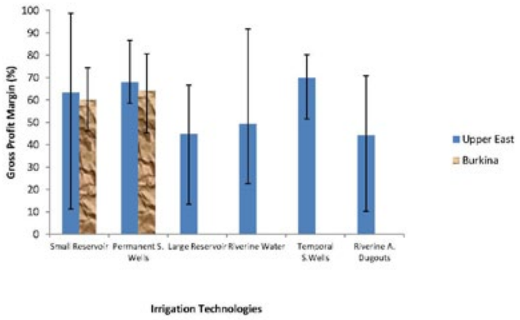

Figure 6: Gross profit margin for tomato production

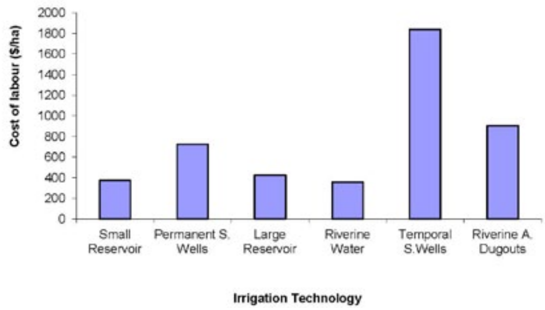

Figure 7: Cost of hired labour in production

and harvesting. Women are mostly hired for transplanting and harvesting of tomatoes, rice and pepper by farmers.

Figure 6 shows that if one ha of tomatoes is cultivated using temporal shallow wells, an amount of about $2,000 goes to the community in the form of labour mainly for digging the wells. The lowest contributor of income in the form of hired labour to the community is the riverine water technology (Ofosu 2011).

3. Potential factors influencing expansion of flood based irrigation

3.1 Market expansion

The potentials of output market for irrigated products are likely to increase in the near future and as such capable of influencing future irrigation development in the basin. Future markets for vegetables are expected to increase due to: (1) the rural-urban migration, by 2030 60% of the world's people will live in cities; (2) population growth; (3) changing food preferences and changing social priorities; (4) achievement of the millennium development goals; and (5) regional integration and free trade policies (Ofosu 2011).

3.2 Appropriate and affordable irrigation technologies

The availability of appropriate and affordable irrigation technologies is one of the factors that influenced the current trend of irrigation development. Farmers are likely to explore more efficient and affordable irrigation technologies in the future (Ofosu 2011).

4. Conclusions and recommendations

The findings imply that in order to achieve high impact, irrigation development in sub-Saharan Africa should consider the economic status of the users and their ability to make the best out of the technology in terms of productivity. Moreover, technologies that give farmers full control over the water should be preferred.

Most of the recent irrigation technologies identified in the White Volta subbasin are indigenous and locally managed. Farmers in the sub-basin have successfully managed these technologies because they are simple and relatively inexpensive. The farmers have also seized the opportunity of the presence of relatively cheap and abundant labour to develop some of these technologies. This is a major lesson for irrigation development in sub- Saharan Africa. Irrigation development policies must begin to look at how to empower local farmers to become entrepreneurs (Ofosu 2011).

Such policies should aim to enhance the reliability of markets (both input and output) as the driving force, and facilitate people's access to land and water.

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Colofon

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