

# Status and Potential of Groundwater Use in Ethiopian Floodplains

# 17



Practical Note Spate Irrigation



Spate Irrigation  
Network Foundation

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## 1. Introduction

Floodplains are flat lands prone to inundation throughout a year. These areas can be used for agricultural development using several irrigation and flood control techniques. For example, floods can be diverted to irrigate fields (such as in spate irrigation) or fields can be cultivated when floods recede (as in flood recession agriculture). There is a long tradition of flood farming systems in Asia (e.g. Pakistan, Yemen, Myanmar, Bangladesh, Cambodia, etc.) with recent uptake in sub-Saharan Africa (e.g. Eritrea, South Sudan, Ghana, Mali, Botswana, etc.).

Apart from surface water sources, ground water can provide year round water availability. This requires of technologies and techniques adequate to field characteristics and local conditions. For this reason this paper addresses the technical and financial requirements for shallow ground water use in Ethiopia as well as its potential development.

Shallow ground water is a resource that can be easily accessed and exploited in floodplains. Rainfall and flood flows recharge shallow ground water tables by surface runoff, percolation and seepage. The ground water table (phreatic level) can be found in the first 25 meters. This type of underground water is characteristic of unconfined aquifers. Shallow ground water serves as a buffer storage thus allowing water extraction during dry seasons. Shallow ground water can be accessed at an affordable cost with simple manual digging or drilling techniques. In spite of several advantages compared to hand dug wells and deep drilling techniques, manual drilling technologies are still in infancy in most parts of Africa, including Ethiopia. Therefore it is of interest to assess different technological alternatives and its scope in the Ethiopian context.

Ethiopia has vast water resources which are estimated in 122 billion m<sup>3</sup> with an annual groundwater recharge of 28 Billion m<sup>3</sup>. (Ministry of Water and Energy 2010). Moreover, the potentially irrigable land is 3.6 million ha. However, only about 5.6 billion m<sup>3</sup> of the water resource and 290,000 ha of the potentially irrigable land is utilized so far (Ministry of Water Resources, 2010 and FAO, 2005). The Agricultural Growth Program targets 2 Million ha area for ground water irrigation in Ethiopia. Given the high population growth rates in Ethiopia, the expansion and effective use of shallow ground water supply for both agriculture and domestic uses is mandatory.

The spate irrigation network (platform co-convened by MetaMeta and UNESCO-IHE) has been promoting and supporting spate irrigation through applied research and training for students and professionals. This paper forms part of a series of publications intended to raise attention on spate irrigation and flood farming systems. Given the lack of experts and professionals in this specific field, it is the purpose of this paper to help contribute to a better understanding of how these systems work and the potential scope for their development.

Following this introduction, the report will briefly describe: the general characteristics of floodplains (Chapter 2), how shallow ground water can be tapped through various technologies (Chapter 3), what are the current uses of shallow ground water in Ethiopia (Chapter 4), a costs analysis of the different options for each technological alternative (Chapter 5), the potential for shallow ground water development in the context of floodplain agriculture (Chapter 6) and to finalize with conclusions upon the findings of the report (Chapter 7).

## 2. General features of Floodplains

Floodplains have several characteristics which make them prone for agricultural development. The combination of surface and ground water together with fertile soil properties allow year round cultivation.

### 2.1 Soil typology and fertility in floodplains

Alluvial soils are soils formed by sediment deposits of fine texture with good fertility characteristics. There are four common type of soils:

- Vertisoils: from basic rocks deposited by sedimentation, high content of expansive clay, almost impermeable when saturated, ideal for rice and other crops such as cotton and sorghum.
- Fluvisols: young soils in alluvial deposits, sedimentation from rivers, good natural fertility, good for dryland crops and irrigated rice.
- Gleysoils: characteristic from wetland soil, made of unconsolidated soils (fluvial, lacustrine and marice sediments), developed where drainage is insufficient (reduced environment).
- Cambisoils: young soils with no clear horizon differentiation, formed by medium and fine



Figure 1: Soil Layer composition in the Fogera Floodplain, Ethiopia

texture materials, mostly in alluvial, colluvial and Aeolian deposits, good for agricultural land.

Floodplain soils can also include sand and gravel deposits. Gravel and sand are ideal layers for manual drilling and ground water extraction. Sand and gravel are very permeable thus allowing rapid recharge of shallow aquifers and manually drilled boreholes.

## 2.2 Characteristics of shallow aquifers

Shallow aquifers are referred as saturated permeable soils subject to water extraction in the first layers (or horizons) of soil (down to 1.5 metres). Usually this happens before the bed rock is reached. This type of aquifers are classified as unconfined, as the bedrock form the confining layer. The aquifer below the bedrock is defined as confined aquifer. Shallow aquifers are recharged through runoff and infiltration from rain and flood water. Depending on the topography, water can also percolate in through underground water flows coming from higher levels.



Figure 2: Typical alluvial soil cracked by loss of moisture

## 2.3 Irrigation and Agricultural practices in floodplains

There are four major categories of irrigation and agricultural practices in floodplains:

- Flood recession agriculture<sup>1</sup>: in which floodplains are inundated and cultivation is practised on receding floods using residual moisture. A variation is river bed farming – where not just the floodplains but also land inside the river beds is used (increasingly common in South Asia);
- Spate irrigation: where short term floods are diverted from ephemeral streams – this technique has a long history in Yemen, Pakistan and North Africa but is expanding in the Horn of Africa. Two variations are: seasonal rivers flowing for a number of months before falling dry and peak flows from unregulated perennial rivers that may be diverted for farming and other purposes too;
- Agriculture around temporary wetlands located in depressed lands (such as dambos): common in other humid areas in West, Southern and Central Africa;
- Inundation canals and dug outs: Whereby land is irrigated by canals fed by temporarily high water levels in rivers – this was the system common in ancient Egypt and still common in parts of Sudan.

<sup>1</sup>: Additionally to flood recession, flood rising agriculture can be practised when water levels are still rising. For this type of agriculture floating varieties (such as floating rice, *Oryza glaberrima*) are used. Both types of agriculture were identified by Harlan & Pasquereau (1969) who named it as *crue* and *decrue* agriculture.

Methods	Techniques	Average Depth (Meters)	Geology	Advantages	Drawbacks	Execution Time (Days)
Manual Auger	Manual Auger	10-15	Sand, silt, clay (soft soils), gravel < 4mm	Easy to use	Temporary casing difficult to remove when there is a thick layer of clay	1
Sludging	Madrigill, rotary, emas, rota-sludge	20-35	Sand, silt, clay (soft soils), soft consolidated formation (alterites)	Easy to use	Significant water consumption in permeable soils	2-4
Washbore	Jetting, washbore	6-15	Sand and silt	Past	Needs a significant volume of water over a short period of time	<1
Percussion	Percussion, stone hammer	15-25	Consolidated formation (laterite, rock)	Adapted to hard formation	High cost of equipment and not always available in time	7-10
Motorized auger	Motorized rotary, PAT-Drill 201	35-45	Any type of rock free consolidated formation	Fast in hard soil	Significant consumption of water, equipment, and implementation cost very high	1-5

Table 1: Different manual well drilling techniques (Source: Abric et al. 2011)

### 3. Shallow Ground Water Extraction – Access and Water Lifting Technologies

Hand dugwells are common throughout Ethiopia and are constructed in many different ways. However manually drilled shallow tube wells are still uncommon. This type of low cost and simple technology includes several methods using only human labour. Drilling techniques include hand augering, percussion, sludging and wash boring (or jetting). Organizations such as IDE and the Oromia Water Bureau, have introduced shallow tube well in a number of locations, using simple and rotary sludging in particular, although this type of technology has not been fully implemented in the country. The table below exposes pros and cons of manual drilling techniques.

#### 3.1 Hand Dug wells

Hand dug wells have been a traditional source of ground water. Though regarded as a simple

technology, it requires significant amounts of labour and time. Hand dug wells are not suitable for certain soil types and contexts (e.g. in floodplains they are prone to collapsing after the rainy season). They are normally constructed with big diameters (between 1 and 10 metres<sup>2</sup>) in order to recharge it through ground water seepage and surface runoff. This type of wells can be found in Ethiopia with depths of 45 metres, but normally its depth varies between 5 and 30 metres deep. Water lifting can be done through traditional rope and bucket (mainly for domestic use), windmill, rope pump, motorised centrifugal pumps<sup>3</sup>.

#### 3.2 Dug Outs

Dug outs are another way of water storage in floodplains (common in west Africa). They can be defined as excavations (mechanically or manually) done in floodplains of rivers or streams. Water is collected mainly through surface runoff through diversion channels of streams. They are meant to collect and store water in the rainy season for later use in aquaculture, livestock farming,

2: Normally constructed with circular shape. Bigger diameters entail higher costs for both excavation and lining. Diameter also depend on material availability, expected soil formations and ground conditions.

3: Diesel pumps have high extraction rates so they can be less suitable as the water yield from hand dug wells is not very high. For deep extraction pumps can be suspended at medium depth and the engine place at surface level using a drive belt to power the pump.

Pump technique	Water demand (flow requirement)	Water table depth (metres)	Financial requirement
Bucket and rope	Low	Up to 15 (or more sometimes)	Low
Rope pump	Low	Up to 35	Medium
Treadle pump	Medium	Up to 7	Medium
Diesel pump	High	Up to 7	High
Micro pump set	Medium-high	Up to 7	Medium

Table 2: Suitability of pump techniques

irrigation and water domestic supply.

### 3.3 Pump alternatives

The extraction of shallow groundwater potential is determined by the soil type, static water level, and user requirements (e.g. cost, capacity, availability). Suction pumps cannot extract water beyond 6 to 7 metres depth.<sup>4</sup>

If the static water level is situated deeper, the pump must still be installed within this range, e.g. by means of an excavation next to the well. This is not desirable for floodplains, as excavations collapse easily during the rainy season. The alternatives, i.e. rope or deep-well pumps could be used to extract water beyond 7 m, but the required installation impedes its mobility.

Table 2 provides an overview of the available pump alternatives for shallow ground water use. The suitability of each alternative is determined by the flow requirements, water table depth, labour requirements and irrigated surface. Treadle pumps and rope pumps are low cost technologies being implemented in Ethiopia

(developed by organizations like iDE and JICA). Treadle pumps require little maintenance. They can carry water over 100 metres on flat land or lift 7 metres above the level of the pump. Water delivery is 1.4 L/s at 4 metres depth (Olley, 2008). Rope pump water delivery ranges between 0.17 L/s at 35 metres depth and 0.67 L/s at 10 metres depth (Olley, 2008). Rope pumps can extract up to 35 metres.

Motorized pumps are another alternative for water extraction. The diesel pump (5 hp) are very common in Asia and Africa. However the technical characteristics make them oversized for the average Ethiopian plot size (between 0.25 and 0.5 ha). The average water delivery is 10 L/s with 6 metres total head with fuel consumption of 1 litre per hour (Bom et al., 2002). Extraction depth is no more than 7 metres. On the other hand small petrol pump sets is an innovative option with significant less cost for both purchasing and fuel consumption. Another added value is mobility due to its reduced weight (10 – 12 kg) endeavouring pump sharing among farmers.



Figure 3-4: Rope pumps in Ethiopian floodplain



4: Note that at higher altitudes suction depths decrease by one meter per 1000 metre altitude.

**Box 1: Chinese low cost micro pumpsets**

Motorised suction pumps are the most popular pumping technology for small scale irrigation in floodplains, since they are physically less demanding, widely available and easy to install.

The African market knows a large range of diesel pumps between 2.5 and 5 hp. The suction depth is 8 m maximum, the total dynamic head is around 20 – 30m. To reach groundwater that is situated deeper, the pumps can be installed inside a large dug hole. The models from 3.5 – 5 hp can be used to irrigate 1-2 ha, which largely exceeds the average irrigated plot size cultivated by smallholder farmers. These pumps are also difficult to transport and know an excessive fuel consumption if used for small fields only. Models from 2.5 – 3.5 hp are notably lighter, though still exceeding 50 kg. These pumps can be used to irrigate fields of 0.5 – 1 ha (Abric et al., 2011). Since most smallholder farmers have smaller fields, they tend to run the pumps on a low rate that is not fuel efficient.

A recommended alternative is the use of Chinese micro pump-sets of 1.5 – 2.5 hp. Its flow of about 3 L/s can be handled by smallholder farmers to irrigate fields of around 0.5 ha. Fuel consumption is more efficient and with a weight of 10 kg farmers can carry them home daily.

**3.4 Advantages and Constraints of water extraction from shallow aquifers in floodplains**

Below are the main advantages and disadvantages identified for water extraction of shallow aquifers.

**Advantages:**

- Year-round water availability: Accessing shallow groundwater resources alleviates water scarcity in dry seasons. Moreover water can be used ad hoc and thus enhancing irrigation practices
- Aptitude for low cost technologies: The unconsolidated soils and shallow water levels allow for to the use of manual well drilling and low-cost pumping technologies.
- Optimal water extraction yields: average

plot area in Ethiopia averages 0.5 ha, which requires reduced water flows (between 1 and 4 litres per second) characteristic of shallow well water extraction.

- Local capacity building: Water extraction and manual drilling technologies require human labour and supply chains developed locally which strengths local economies.

**Constraints:**

- Clay layers decrease water yields: Especially lacustrine floodplains are characterised by thick clay layers. Water extraction from such impermeable soils is only feasible by means of seepage in large diameter wells. Tube wells cannot generate sufficient yield in these soils.
- Pollution hazards: shallow groundwater is more sensitive to pollutant sources from superficial and subsoil sources (sewage, runoff, etc.).



Figure 5-6: Motor pumps in lake koka floodplain



## 4. Ground Water use in Ethiopia – Field Experiences

### 4.1 Agricultural land uses in Ethiopia

Land use in rural Ethiopia is characterised by pastoralism and agro-pastoralism. Pastoralist communities rely on cattle as a source of income. However they become vulnerable to climate change effects as unreliability of rain constrains grazing and water use for livestock. On the other hand, agro-pastoralists combine both livestock raising and agriculture as a source of income. During the rainy season they are occupied in agricultural practices while in the dry season they prepare the land for the next season and are occupied in livestock raising activities. This duality in land use can cause some dispute over water resources, especially in the dry season. Therefore the exploitation of shallow water can alleviate pressure on the resource. Moreover shallow ground water use can be a driver for pastoralists to turn to agro-pastoralist activities and making them more resilient to climate unreliability.

### 4.2 Land tenure

Under Ethiopian Federal law, land is owned by the government. Farmers are entitled to use the land. However, they have the right to rent it to others. It is common for farmers to rent out their land to investors. This rental can be either with an annual payment (e.g. 5,000 to 6,000 birr/ha in Lake Koka) or splitting profits (investment is always covered by tenant) from agricultural outputs. It is also common for farmers to only rent in the dry season. Digging and maintenance costs

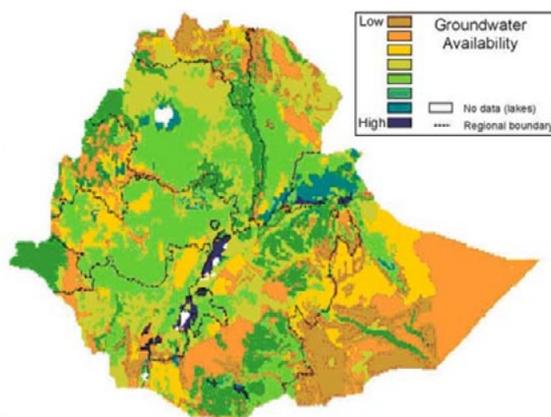


Figure 7: Groundwater availability in Ethiopia (Source: McDonald 2001)

of dug wells are always covered by land tenants. Field visits were carried out in order to assess areas prone for shallow ground water development. These comprise four regions; Oromia, Amhara, South Nations Nationalities and Peoples (SNNP) and Tigray.

### 4.3 Oromia Region

The Oromia Region is the biggest and most populated region of Ethiopia covering 284,538 km<sup>2</sup> and with an approximate census of 27 million inhabitants. It is centrally located bordering all other regions except for Tigray. Several locations have been spotted for shallow ground water potential.

#### Lake Koka Floodplain

Location: Lake Koka is located southeast of Addis Ababa, 100 km away by road.

Farming and agropastoralist activities: Due to permanent flooded areas during the rainy season (from mid-June to September) flood farming is the main activity in the area. Difficult access of flooded land discourages livestock rearing for farmers. Onion and tomato are majorly cultivated crops in which the respective yield per hectare per season is 350 and 300 quintals. Water-melon, Maize and Cabbage are also cultivated. Furthermore, there are two irrigation seasons in a year, the first season being from October to January and the second one between February and May. Around the area, there is no practice of cultivation using residual moisture, except some farmers who harvest chickpea using residual moisture. However, no canal structures are built to manage water and improve residual moisture.

Soil conformation and water table: Inspection of locally constructed hand dug wells, in Dungugi village, revealed water tables varying from 3 to 10 metres deep (dynamic water table<sup>5</sup>). These wells are between 10 and 14 metres deep. The dominant soil type of the flood wells land is clay loam soil at the ground and its clay nature increases with depth. These alluvial soils are the result of sedimentation through flooding. Sandy layers are not common and rarely encountered.

ShGW use: Hand dug wells are abundant in the area, as the floodplain is characterised by intensive dry-season cultivation and irrigation. Now, almost every farmer or land owner has its

5: Dynamic water table is defined as the varying depth of shallow ground water table (phreatic level) throughout a year. This difference in level is caused by recharge and percolation process during rainy and dry season.



Figure 8-9: Hand dug well constructed around Koka dam

own well. The common practice was to pump the river discharges from Awash and Mojo rivers. As the area is flooded every rainy season, many wells are situated just outside the floodplain. In the dry season, water from those wells is pumped into the floodplain using powerful diesel pumps. Wells situated in the floodplain are covered during mid of June using wood, plastic and/or geo-membrane materials to protect them from flooding. Then they will be cleaned (including inner part of the well) at the end of September. If they are not covered, then they will collapse and the owner will be forced to re-dig the well. The source of the flooding is the river discharge from Mojo River.

**Pumping technology:** The commonly used pumps are diesel type surface pumps, namely Kama KDP 30 X, having a delivery head of 13 m, suction head of 7-8 m and maximum discharge of 30 m<sup>3</sup>/hr. Normally, pumps around the area are surface pumps and the users move them during rainy seasons.

### Becho Plain Floodplain

**Location:** The Becho flood plain is located in South Western Shoa zone between Tegi and Sebeta Hawasa weredas, located 50 km away from the capital Addis Ababa. This plain has some similarities with the Koka flood well in terms of its inundation and flooding.

**Farming and agropastoralist activities:** On the dry season irrigation through pumping from Awash River is the major activity while livestock rearing is rarely practised. The main reason for the limited production of livestock is similar to that of Koka flood plain. The experience of pumping the Awash River flow is expanding upstream of the river resulting in a reduction of the discharge for downstream users. Similarly to Koka flood plain, the area is flooded by River Awash every rainy season beginning of August till the end of September. Then farmers will cultivate Teff, starting mid-August up to end of November using a combination of residual moisture and flood recession irrigation. They also cultivate chickpea, Lentil and Bean starting from September onwards

### Box 2: Towards Productive Shallow Wells in Lake Koka Floodplain

In Koka, the existing hand-dug wells mainly face problem of collapsing and sediment deposition due to the flood. Farmers every year either have to construct new hand-dug well or clean sediment from the wells. This is labour intensive, costly and may also result in a loss of a complete harvest if the reconstruction work is not done timely.

As an alternative to the hand-dug wells, stone riprap, shallow-tube well and lining methods were assessed using the benefit-cost ratio. Stone riprap and lining of existing wells resulted in the highest (3.3) benefit cost ratio. Lining of existing hand-dug wells together with frequent irrigation interval and fertilizer application will benefit farmers as it leads to a net income of 66,122 Euro. In addition, the variation between lining of existing wells and shallow-tube well application is significant; that is net income of shallow-tube well is 65,752 Euro. Therefore, farmers which located in ground water depth up to 8 meter and those farmers with 100 meter distance from Mojo River will be benefited.



Figure 10: Hand dug well in Becho plain

using the residual moisture. In the irrigated fields, it is common to cultivate two seasons per year, the first season being between November and February and the second season between March and May. Maize, Tomato, Onion, and Cabbage are the main crops grown.

Soil conformation and water table: The soils of the flood well are generally deep, dark brown to dark in color, alluvial deposited dominated with textural classes of clay. These soils have expansive and contractive characteristics with and without moisture. Some of the soil layers up to one metre have collapsing nature. Surface stoniness was not present and salinity indicators were observed. These soils are also the result of sedimentation due to flooding and possess good. At the locations visited the dynamic water level varies between four and seven metres.

ShGW use: The western part of the Becho plain knows a considerable amount of tube wells, implemented by the non-governmental organisation iDE (International Development Enterprise). All wells have been drilled using simple sludging. The districts in the east of the plain were not part of the operative area of iDE and the number of tube wells is limited to a few trials. Hand-dug wells are not common in Becho due to the collapsing nature of the black clay soils. Observations in Becho also showed another water harvesting method: a small pond. The main purpose is that the pond serves as a storage reservoir during the rainy season. The second purpose is that the area is inundated during rainy seasons and the excavated earth materials from the pond were used to construct a small dike structure that protects his residential areas nearby his field.

### **Sululta-Degem Floodplain**

Location: This area has a good potential of shallow ground. This area can be accessed through Addis Ababa to Bahir dhar road. This

vast wet land is located at a distance ranging between 40 km at around Sululta to 120 Km around Degem. The area has a rich experience of utilizing hand dug and shallow ground water, for domestic water supply purposes. Within this floodplain, it is also common for the villagers to construct hand dug wells.

Farming and agro-pastoralist activities: Livestock agriculture and rearing along with crop production have been the main sources of income until now. However, the majority of the farmers are focusing on the quality of the end products derived from livestock. As a result, the livestock production is shifting from local species in to hybrid species. Consequently, the number of animals reared by every household is decreasing. Like the other floodplains visited, the agronomic practices during dry season have similar characteristics. Main crops grown are Tomato, Onion, Potato, Garlic, Cabbage etc. In some areas like the Gaje village around Sululta farmers harvest seedlings of Eucalyptus, Geho (Acacia Decrense), Gravila and Tid. Yet, during rainy season this wetland is not cultivated as the water table reaches the surface. Moreover, flood recession and use of residual moisture is not practised.

Soil conformation and water table: The texture of the soils within this flood plain is clay having greyish color in some areas, and redish brown. Salinity indications were observed in some areas such as the Dokacha and Wertu villages. Recently, some model farmers have started utilizing hand dug wells for irrigation purposes. In the majority of the wells visited, the water level varies between 1 to 5 m. In some areas like the Dokacha, the water level is at the surface (even during April). The average recovery time is about 3 to 6 hours for 2 m deep and 1 m diameter well. Therefore, farmers could irrigate twice a day (morning and afternoon).

ShGW use: The experience of using wells for irrigation purposes is very limited around the area but, it is expanding. There is also an experience of pumping river discharges in to underground ponds for use the dry season. Ponds are covered with geo membrane to reduce seepage losses. Hand-dug wells observed are limited to high-value protected wells like used elsewhere as potable water points. Firstly, the wells are dug, in a circular shape having 0.8 to 1 m diameter, manually using simple hand tools such as crowbars and shovels. Then, concrete pipes that are perforated at some intervals throughout their circumference will be inserted into the dug holes. This helps to stabilize the well and the

	Before 1990 (Derg regime)	2005 Election	2010 Elections	2013 (Now)
Farming systems	No knowhow on irrigation	Introudction of traditional irrigation	Beginning well irrigation	Using well irrigation with pump
Number of flooding events per year	no	no	no	no
Number of livestock animals	30	25	20	12
Quality of livestock products (fattening and milking)	low and local species only	Beginning of using hybrid varieties	Expansion of hybrid varieties to almost 1 at each household	Many hybrid varieties and higher quality of products
Fishing number of wells	no	no	no	no
Number of wells	0	75 (for WS purpose only)	130 (more than 95% of them for WS purpose only)	357 (including 87 of them for irrigation purpose)

Table 3: Timeline event in Sululta-Degem

perforation will help the water drain into the dug holes. Finally, a concrete slab, which is reinforced using wooden bars, is used to cover the hole. For pumping purposes, small openings will be left over the slab. The most commonly used extraction method is rope and washer pump. The construction cost of the hand dug well including the rope and washer pump is 12,000 -15000 Birr depending on the depth.

#### 4.4 Tigray Region

Tigray Region lies in the north of the country, bordering with Eritrea, Sudan, Afar and Amhara Region. It has an estimated population of 4.3 million inhabitants. Alamata woreda is located south of Tigray and is known for its land and ground water resources. In this woreda it is common to use deep wells for irrigation. Recently IFAD through PASIDP (Participatory Small scale Irrigation Development Program) is financing the irrigation system of six schemes in the woreda to upgrade to pipe supported furrow irrigation system. There is a long tradition of river diversion for spate irrigation.

##### Tumuga Waja

*Location:* The Tumuga (Waja) flood well is located in Tumuga kebele and Betemaria village. It can be accessed by driving 20 km South of Alamata on the way to Addis Ababa road.

*Farming and agropastoralist activities:*The livelihood of the area depends mainly on rain-fed and irrigated agriculture supplemented by spate

irrigation. Secondly, livestock rearing is practiced, where every household owns some cattle normally employed for ploughing purposes. The area is characterized by its expansive nature of wet land thereby decreasing the cultivable/irrigable land and additionally incrementing salinity concentrations.

*Soil conformation and water table:*The study undertaken in 2005 by Tigray water resources Bureau reveals that, the water table of the area is less than two metres deep from the ground. Farmers around the area are able to dig about eight blocks of drainage outlet (canal) structures across the wet land, and irrigate about 440 ha of land. Nonetheless there are salinity concentrations in the water affecting two blocks of outlets. The dominant soil type of the flood wells land is very deep loam soil which ranges from sandy loam at the upper reach to clay loam at the lower reach.

These soils are the result of accumulation throughout the years by erosion from the surrounding high lands. For long period of time, farmers of this area have diverted floods into their farms. This flood brings in fertile sediment. Each year the natural soil will be totally covered by a considerable depth of transported soil sediment.

This phenomenon is typical in most cultivated lands of the Raya-Valley. The other soil type is clay loam which is found in areas that are getting fewer floods, yet flooding is contributing to some

Description	Tumuga	Kulugize Lemlem	Gerjele	
Total area irrigated by spate (ha)		536	617	742
Community hand dug well (number)		52	144	258
Private hand dug wells		27	16	55
Cultivable land (ha)		3.885	2.929	3.510
Private hand dug wells in construction		69	83	100
Community hand dug wells in construction		34	63	71
Spate irrigation under development (ha)		114	200	288

Table 4 Summary of the number of wells and area under irrigation of Alamata Wereda flood well Kebeles.

extent in modifying the texture of the soil. The third soil type of the study area is clay. This soil is mainly found in areas where farmers are not using floods.

The probability of getting sand within 10 meters depth is almost zero. The dominant geological formations found in the flood well area are unconsolidated sedimentary basin-fill deposits. Observation of the well log data of most of the drilled flood wells visited indicate that the alluvial deposits are composed of intercalating layers of gravel, sandy gravel, sand, silty sand, clayey silt, silt, silty clay and clay.

ShGW use: The water table is located at shallow depth, thereby the area cannot be cultivated during rainy season; as water raises and reaches the ground level. Downstream of the flood wells farmers divert the discharge from the blocks of the drainage canals, traditional spate irrigation, hand dug well and borehole irrigation. Construction of hand dug wells is expanding through it was firstly introduced three years ago. The water table around the area is located at a shallow depth which is less than eight metres. The cost of a well is 50,000 Birr. Last year it was 40,000 Birr. A similar well, which is financed by IFAD-PASSIDP having a depth of 10 to 12 m, currently costs 105,000 to 115, 000 Birr in neighbouring woredas of Tigray.

The same well had charged 70,000 to 80,000

Birr last year. The organizations involved in financing the construction cost of the wells are the World Bank through its Agricultural Growth Program (AGP), government through its Safety net program and its MDG (Millennium Development Goals) Fund and World Vision Ethiopia. Construction of the wells is undertaken by private contractors. Construction of traditional spate schemes are handled by the farmers and construction of modern spate schemes are managed by governmental enterprises. World Vision Ethiopia is also involved in facilitating credit and aid for buying pumps.

The irrigation capacity of the community owned hand well as per the design is 3 ha. But practically it does not exceed 1 ha indicating that the well discharge is nearly 2 l/s. The agronomic demand for small scale farmer managed schemes is 2 l/s/ ha. The irrigation capacity of the private owned hand dug well as per the design is 1 ha. The agronomic practices between the spate irrigation and hand dug well irrigation are different. In hand dug well they cultivate onion, pepper, maize, Mango and sorghum. But in spate they cultivate maize, sorghum and other cereals. Areas having hand dug wells are more benefited than the spate irrigated areas mainly because the wells can serve through the dry season but the spate irrigated areas can only be served only during wet seasons. The same area can be irrigated by both systems depending on the period or season.

Layers	From	To	Lithology	Lithologic description
1	Ground	0.5 m	Alluvial deposit	Sandy loam
2	0.5 m	6 m	Alluvial deposit	Clay loam to Black cotton clay soil

Table 5: Soil sample Tumuga Waja



Figure 11-12: Flood wells around Tumuga and Waja, Tigray

**Pumping technology:** The most common extraction methods of the hand dug wells are using labour and rarely using motorized pumps. The most commonly used engine pumps are diesel type, Boshan HL80CL. This pump is characterized by maximum delivery head of 28 m, suction head of 8 m, maximum discharge of 1000 lit/m and 6 horsepower. Though there is higher demand for the diesel pumps, the operational cost is expensive.

**Gerjale**

**Location:** This flood well is located in Gerjale kebele, Agamte and Adishahshum villages. It can be accessed by driving 14 km North of Alamata on the way to Mekoni-Mekelle road. Then, a drive of 4 km north on a dry weathered road is required.

**Farming and agropastoralist activities:** The livelihood of the area depends on rain fed agriculture supplemented by traditional spate irrigation and livestock rearing. Hand dug wells (manually and mechanically dug) are beginning to expand. The introduction of these wells started three years ago. When the well is manually dug it is stable even if it is not lined. But when it is dug using excavators, it has the problem of sliding and getting widening. The problem is mainly associated to poor quality of well construction. This is attributed to lower skill of the contractors involved.

**Soil conformation and water table:** The soil types within the floodplain are very similar to that of the Waja-Tumuga soils as all the soils are transported due to erosion at the upstream hills. Likewise, the land use type is also the same. The probability of getting sand within 10 meters depth is almost zero. The dynamic water table varies between 4 to 6 m deep from the ground and the static water level is found at 6 m.

**ShGW use:** Floods in this area are truncated conic type in shape having 8 m diameter at top and 4 m diameter at bottom. The wells have also a cascading ladder type entrance extension. The average depth of the wells excavated is 8 m. The water is pumped out every three hours and it will take 1 hour to recharge. In this case it is possible to pump water from the well up to four times a day. The irrigation capacity of the community owned hand well as per the design is 3 ha. But practically, it ranges between 1 to 2 hectares.

The irrigation capacity of the private owned hand dug well as per the design is 1 ha. The agronomic practices between the spate irrigation and hand dug well irrigation are different. In hand dug well onion, pepper and maize, Mango and sorghum are cultivated. In spate only maize, sorghum and other cereals are cropped.

The number of beneficiaries of each community hand dug well vary between 4 and 7. Areas having hand dug wells are more benefited than

Layers	From	To	Lithology	Lithologic description
1	Ground	0.5 m	Alluvial deposit	Clay
2	0.5 m	7 m	Alluvial deposit	Clay soil
3	7 m	8 m	Alluvial deposit	Clay with some gravel and sand

Table 6: Soil sample Gerjale

the spate irrigated areas mainly because the wells can serve through the dry season but the spate irrigated areas can only be served only during wet seasons.

**Pumping technology:** The average spacing between nearby wells is around 150 m. Within the kebele there are 55 community owned hand dug wells and 203 private owned hand dug wells. The most common extraction methods are using labour and rarely using diesel pumps. The most commonly used diesel pumps. Though there is a higher demand for the diesel pumps, their investment and running cost are high.

#### **Kulugeze Lemlem**

**Location:** Kulugeze Lemlem is located in Alamata Woreda, Laelay-Dayu kebele. It can be reached through the asphalt road after driving three km north of Alamata.

**Farming and agropastoralist activities:** Agriculture is the main stay of the population in the area. Mixed farming is practiced with crop cultivation as a major practice followed by livestock rearing.

**Soil conformation and water table:** The static water level in the Kulugeze lemlem area varies from 0.5 m to 2 m. The soil is silt/clay type at the top (less than 1m depth) and then becomes silty and sandy type with depth. From deep boreholes in the Alamata plain, the thickness of the soil in the area is over 80m. The excavated hand-dug wells did not reach the bedrock. However, from deep boreholes the bedrock is volcanic type (basalt with some pyroclastic rocks) (Huisman Foundation 2014).

**ShGW use:** Most of the wells constructed are about eight metres deep and the dynamic water level varies between four and six metres. The average spacing between the wells is 100 m. This well has an irrigation capacity of four ha and it is among the best wells in terms of its stability and supplying reliable discharge. Its recovery time is two hrs. Mr. Tebeje Alemayoh Abera is a model farmer. He was able to dig his private well for irrigation purposes. He also bought a treadle pump for lifting water from his personal hand dug well. World vision Ethiopia and AGP have helped him and his 10 neighbours in partially financing the cost of a surface pump and the hand dug well respectively. This well has an irrigation capacity of four ha and it is among the best wells in terms of its stability and supplying reliable discharge. Its recovery time is two hrs.

**Pumping technology:** The method of extraction is using diesel type surface pumps, usually Boshan

and Rubin, and manually driven treadle pumps.

### **4.5 South Nations, Nationalities and Peoples**

The Regional Irrigation and Natural resources development office pointed out Mesken, Silti and Mareko as the most suitable districts for shallow groundwater development.

#### **Mesken-Silti and Mareko Woredas**

**Location:** These weredas are neighboring to one another in which the center and bigger city around is Butajira. Butajira can be accessed either through Addis Ababa-Zuway-Butajira road which is 220 km south of Addis Ababa or through the Addis Ababa-Sebeta-Butajira road which is 130 km away from Addis Ababa. The distance to Kibet, the capital of Silti wereda is 15 km south and the distance to Koshe, the capital of Mareko wereda is 25 km east from Butajira.

**Farming and agropastoralist activities:** Livelihood of the area is dependent on rainfed agriculture which is supplemented by hand dug well irrigation. In these areas, livestock production is very limited to not more than one cattle per household as the area is densely populated and they have very small area for forage production.

The construction of hand dug wells began more than forty years back during the Emperor Haile Selassie time. At the beginning, the purpose of digging wells was to use them for domestic and livestock water supply purposes. Thereafter the wells were constructed to prepare seedlings and small garden irrigation within the residential compound. Recently, they are dug for irrigation purposes. In these areas, a well is found almost in every compound.

Recently, they are dug for irrigation purposes. In these areas, a well is found almost in every compound. Agronomic practices around the area are based in two dry seasons, October to January and February to May. Onion, Tomato, Cabbage, Spinach, Red beets, Carrot, Chat, and Pepper are the main crops. During wet seasons (June to September) Maize, Wheat and Mustard are the most common choices. In cases of short rainfalls periods, farmers have to supplement with water to their land through irrigation using wells. The area is known for its good yield of pepper, in a good season it yields 12 to 18 Quintals per ha/season. But due to viral diseases, the yield is now reduced to 4 Quintals/ha/season. As a result, farmers are now reluctant to cultivate pepper. Marketing system is also similar to the other sites visited. The farmers/investors do not have an absolute right to



Figures 13-14: Discussion with farmers, wereda and kebel experts of agricultural and rural development office and traditional hand dug well in Mesken wereda

fix prices.

**Soil conformation and water table:** Soils are generally with textural classes of black cotton clay. In some of the areas the access is problematic as the rain has increased the stickiness of the clay soil. Majority of the clay soils are generally deep and thick (>450 cm) having a flatter topography. Surface stoniness was not present and salinity indicators on the field were not observed. Sand and gravel are obtained at an average depth of 8 meters depth, and this layer is used as an indicator for reaching the aquifer. But in Silti wereda sand can easily be obtained at 2 m depth. The dominant land use type of the area can be categorized as agricultural land with some forest land. In the area it is also common to rent irrigation land but, the investor will have a use and even a digging right at his expense. The agreement is to renew the contract annually as the rent cost is increasing annually.

**ShGW use:** This well was constructed for training purposes by the ministry of Agriculture in collaboration with World Bank through its program called AGP (Agricultural Growth Program) at a cost of around 17,500. It was constructed through a combination of hand digging and one of the simple manual drilling techniques called jetting. In the area, only government through its Food Security project is involved in the construction of the community hand dug wells.

This well was constructed to have a dimension of 3 m by 3 m by 4.5 m (length, width and depth) so that the pump could be located below ground level (reducing the suction head). Furthermore, the well is 24.5 m deep in which the remaining 20 m are circular 1 m diameter holes in which the deepest 12 m and the upper 8 m deep are reinforced with 4.5' and 3.5' pipes which both

are covered by casing. The well is also equipped with cascading stairs made of earth materials that enable mobilization of the surface pump in and out of the well.

According to Sileshi, head of the irrigation department of the wereda agricultural office, the training was composed of two days theoretical and fifteen days practical. This training was an extension of the training provided last year in Zuway by Ministry of Agriculture and their Sudanese counterparts. The third phase training will also be held in Gojam next year.

The other well visited is administratively located in Kurfute village, Ajira kebele, Silti wereda and Silte zone. This well was constructed manually to have 6 m depth and 1 m diameter circular shape. The dynamic water level ranges between 2.5 m and 6 m. As clay soils have expansive and contractive nature, the top 2 to 3 m should be protected using dry masonry to improve its stability. Wells in Silti wereda are flooded during wet seasons. Farmers have developed some strategies to tackle collapsing wells from flooding. Firstly, they locate the wells in elevated areas or not so prone for flooding. Secondly, they cover it using plastic materials. They also cover the wells using traditional house shield. The house is 5 m by 3 m by 3 m and also serves as a shelter for the pump.

In these flood wells it is also common to dig a pump seat pit parallel to the well. Accordingly they are able to reduce the suction head required by the pump to lift water. The well and the pit are interconnected using a very small tunnel (10' size pipe) structure constructed at the bottom of the pit. The dimension of the pit is mostly 3 m by 3 m by 3 m. The number of wells that are used for irrigation purposes is increasing from year to year. For example, when it was first introduced

in 2007 G.C it was only one. In 2012, it was increased to 38 and now they are 43. When manually drilled using local contractors, the well costs 5000 Birr. But the respective cost was 2000 and 3500 Birr last year and the year before. The areas visited have also resemblance in terms of long term and short term government plans.

The long term plan is to enable every household owns at least one option for access to irrigation water; they call it the “water bank alternative”. To achieve this, the woreda agricultural office is working on improvement of soil and water conservation measures. Many percolation pits are dug on the upstream side hills of the wells, so that, the recharge towards the wells is increased. The short term plans however are to increase the number of wells and the number of surface pumps to be delivered through credit services. This can be illustrated by the fact that, the number of wells in Mesken woreda currently is 6800 and the area irrigated using wells and other types of irrigation methods is 1300 ha and 2900 ha respectively. Furthermore, the number of surface type diesel pumps within same woreda delivered has increased from 100 to 480 within a year.

*Pumping technology:* The pumping method utilized within the three woredas is similar. Their first option is for diesel type surface pump, although its investment and operational cost has limited its usage. The woreda agricultural office however has made a package of credit arrangements that enables small farmers to buy a pump. As a result, the number of farmers using diesel pumps is increasing from year to year. However, as the majority of farmers still do not have enough money to buy pumps, the use of traditional bucket-like lifting mechanisms is still abundant.

## 5. Cost Analysis

Based on extensive field observations, literature research and drilling of pilot tube wells, the cost of tube wells for irrigation in floodplains is

estimated at 5,000 – 12,000 Birr, whereas the cost of hand-dug wells for the same usage ranges from 300 to 2,000 Birr (Practica 2013, 2014). This implies that tube wells could only be an economically viable alternative in areas where the use of hand-dug wells is constraint. This is the case in areas with unstable soils, or in floodplains where the static water level is relatively deep and reinforcement with stones or yearly rehabilitation of wells is costly and time consuming. It should be noted that the construction costs of a well highly depend on both the usage and the given local context. The following paragraphs provide more insights in the resulting price variability.

### 5.1 Tube wells for various usages

The price of a well is mainly determined by its usage, as this determines the required level of hygiene, pump type and capacity. Communal drinking water points represent the high-end value, whereas private wells for smallholder irrigation are characterized by the lowest cost. The usage requirements have an impact on the:

- Depth – To avoid pollution, drinking water is ideally not tapped from the first aquifer. For irrigation hygiene is not an issue.
- Pump type and diameter – The diameter of a well is determined to fit a specific pump type. Pumps used for communal drinking points (e.g. Afridev, India Mark II) require a 5” pipe, whereas suction pumps only need a 2” borehole.
- Materials – Certified PVC tubes are required for communal wells whereas low-cost PVC and artisanal screens are sufficient for irrigation purposes.
- Slab – Irrigation wells do not need any sanitary protection, whereas drinking water wells do.

For the cost of water lifting technologies (WLT) see table 7.

Type of pump	Capital costs (Birr)		Maintenance costs (Birr)	
	WLT	Accessories	2010	To date
Treadle	3.650	4.000	375	517
Rope and washer	2.953	200	0	0
Petrol	4.751	1.872	953	1.420
Diesel	7.246	1.971	1.792	2.527
Electric	5.000	1.929	13.000	0

Table 7: Average costs of WLTs provided by farmers. (Source: Gebrehaweria 2011)

Purchase price are considerably higher for motor pumps than manual water lifting technologies partly due to import taxes which account for around 37% of the cost (Gebrehaweria 2011). In a study in East/ West Tigray, the costs for the construction of a 11 meters deep manually drilled water well have been determined.

The cost condition for manual drilled wells is analyzed under different scenarios depending on the depth of the groundwater and the nature of the soil. Assuming a suitable geological formation for manual drilling, the cost of drilling varies depending on the nature of the soil (whether the soil is soft or hard), the depth of the groundwater and the type of PVC pipe installed (Nega 2013). See table 8.

### 5.2: Irrigation tube wells in various contexts

Even if the usage is known, the cost of tube wells is still highly variable. The experience of constructing six pilot wells for floodplain irrigation reveals that the price of a 14m tube well for irrigation would be at least 5,000 Birr for soft soils (about 200 EUR). However, the real costs depend a lot on two factors that are highly variable in different areas: the total drilling depth and location of the well.

The total depth is directly linked to the presence of shallow aquifers, which are not always situated within 14 m depth. Even if groundwater can be found within a few meters, tube wells rely on a water bearing layer of sand or gravel to get sufficient yield. So if this layer starts from 24 m depth, the total drilling depth will go up to 28 m in order to install a sufficiently large filter screen within this aquifer. If the depth is twice as large, the material cost doubles as well since it is the PVC tube that demands the major part of this. The labour cost even increases more than twice, since drilling gets heavier when the depth increases. In this case the price of the well would exceed 10,000 Birr.

Transport is another major component of the costs faced by well drillers. If an area is too far to be reached by local and/or public transport, a vehicle must be hired which costs at least 750 Birr (30 EUR) per day. Moreover, when drilling far from home the drillers must be accommodated in one way or another, which increases the costs as well. Hence, for a manual drilling sector to become economically viable it is necessary that the enterprises are based within their market area. If not, costs increase too much and a well becomes unaffordable for smallholder farmers.

## 6. Potential for Shallow GW use in Ethiopia

There are encouraging figures considering shallow ground water at the national scale. A total of 38 million hectares is the estimated potential area for Ethiopia. This figure can be divided in different potential areas:

- 15 million hectares of extensive regoliths ideal for mechanically drilled wells and hand dug wells;
- 17 million hectares of alluvial and lacustrine deposits appropriate for manual drilling and hand dug well development;
- 3 million hectares of riverine and lacustrine deposits suitable for shallow tube wells and hand dug wells;
- 3 million hectares comprising the periphery of seasonal wadis, best accessed by a combination of sand dams and subsurface dams or flood water spreading and tubewells or dugwells.

Apart from these figures depressions on minor valleys with high ground water tables are also areas prone for shallow ground water use. All of the above areas have been identified and mapped (see figure below for more detail).

Cost type	Scenario one (hard soil)	Scenario two (medium soil)	Scenario three (soft soil)
A 2"gre PVC (suction	14.465	12.815	12.595
B 4" grey PVC (rope pump)	19.963	18.313	18.093
C 5" blue PVC (Afridev)	26.980	25.330	25.110

Table 8: Price indication of different types of wells in Birr (Source: IDEA 2013)



Figures 15-16: Installing sludge drill in Fogera plain

### 6.1 Manual drilling technology

There are several advantages compared to other type of shallow ground water use. Firstly, manual drilled wells are cheaper than conventional hand dug wells or mechanically drilled wells. Therefore the initial investment is lower. Secondly, if compared to hand dug wells, manual drilled wells equipped with apron and capping resist flood events providing water immediately after the rainy season with practically no maintenance costs. As a consequence, cropping cycles can be increased to 3 per year (August to November, December to March, and April to June). Thirdly, water availability throughout the entire year, and especially before the rainy season, can tackle uncertainty regarding the arrival of rains and consequently sowing and harvesting periods.

### 6.2 Business development and value chain

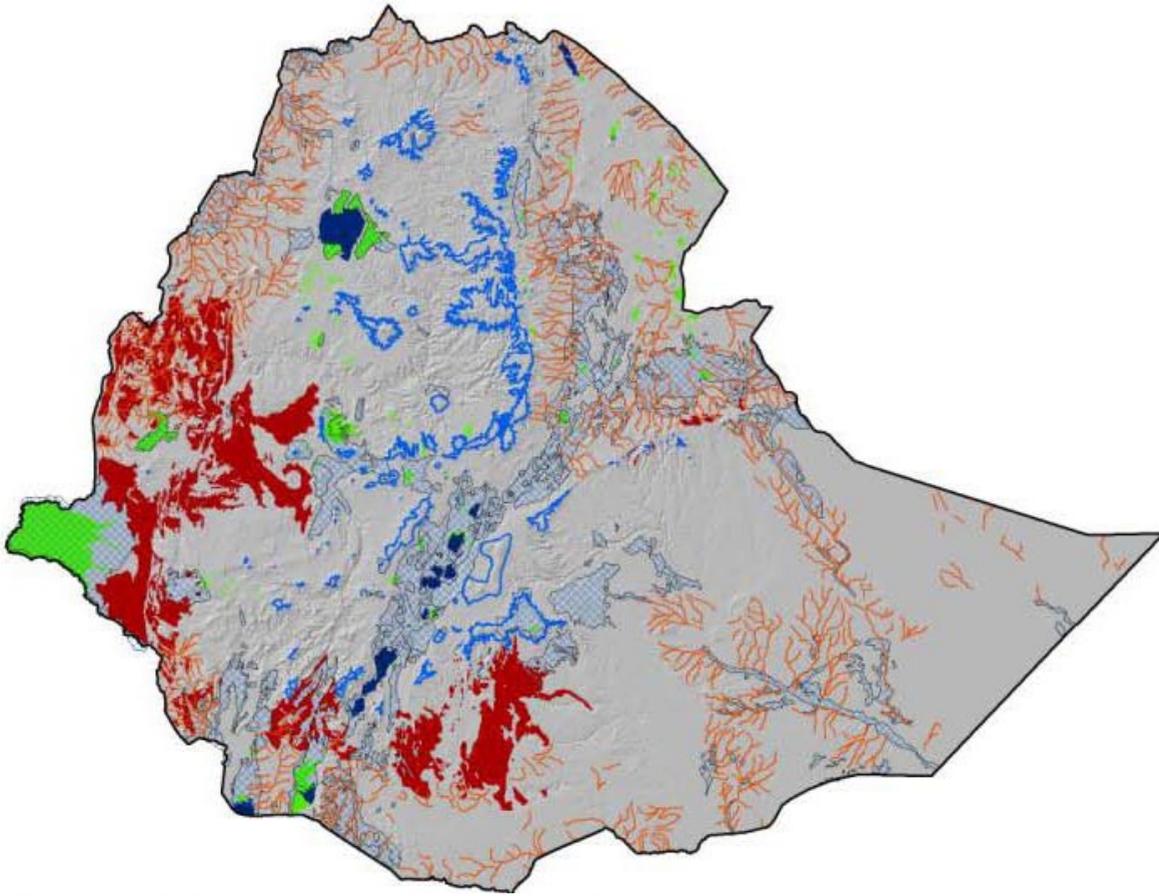
As exposed above, there are extensive areas for shallow ground water use. If proper technological alternatives are applied, irrigated agriculture could develop on new areas. Ergo, commercial agriculture and market openings would be viable. Introduction of cash crops could boost local economies. To do so, value chain development is mandatory. This would encompass technological supply chain of current and proposed technologies (workshops, drill teams, spare parts retailers, etc.), distribution and consumer lines (local markets, farmers associations for product distribution and price control), marketing alternatives (different products with added value) and legal basis for insurance of agricultural products.

### 6.3 Capacity building

The introduction of new drilling technologies, diverse pumping systems, new crops and varieties and improvement of current shallow ground water uses will compromise capacity building programmes at different levels.

Firstly district officials must be familiarized and trained with the proposed technologies and techniques. Thereafter district and local training programmes could be developed. These trainings are already taking place under the supervision and facilitation of the Oromia Water Bureau. Manual drilling techniques are taught to young entrepreneurs so as to develop business activity on drilling of shallow boreholes. Similarly, introduction of irrigated agriculture together with cash crops involve new agricultural practices and techniques (irrigation patterns, disease control, soil fertility management, etc.). Therefore training of farmers should be also prioritized.

The field visits revealed current shallow ground water use. Management could be improved in different matters; namely water lifting technologies, maintenance of hand dug wells and shallow wells, protection measures in hand dug wells for livestock and children and quality control (spacing of wells, salinity, etc.). Consequently, capacitation must address existing management practices and endeavour its enhancement at local level.



## Mapping shallow groundwater for MUS

- Zones of frequent discharge cold springs
- Seasonal Wadis and their catchment; total length > 30000 km; gw storage 3 billion m<sup>3</sup>
- Extensive shallow regoliths (laterites and saprocks), covers > 150000 km<sup>2</sup>
- ▨ Extensive alluvial and lacustrine deposits, cover > 170000 km<sup>2</sup>
- Extensive riverine and lake fringe flood plains; covers at least 30000 km<sup>2</sup>; NB : small ubiquitous depressions not included
- Lakes

Figure 17: Map for potential shallow groundwater sources (produced by professor Seifu Kebede)

## 7. Conclusions and way forward

Shallow groundwater development through low-cost technologies is a key asset to increase the productivity of smallholder farms in floodplains. The study demonstrates current initiatives of shallow groundwater use for water supply and irrigation, and reveals a scope for upscaling appropriate technologies.

Government bodies such as the Oromia and the SNNP Water Bureaus are currently promoting manual drilling technologies through training and local capacity building for irrigated agriculture. This type of initiatives are a way of developing shallow groundwater as an ad hoc resource. However its development is still at primary stage.

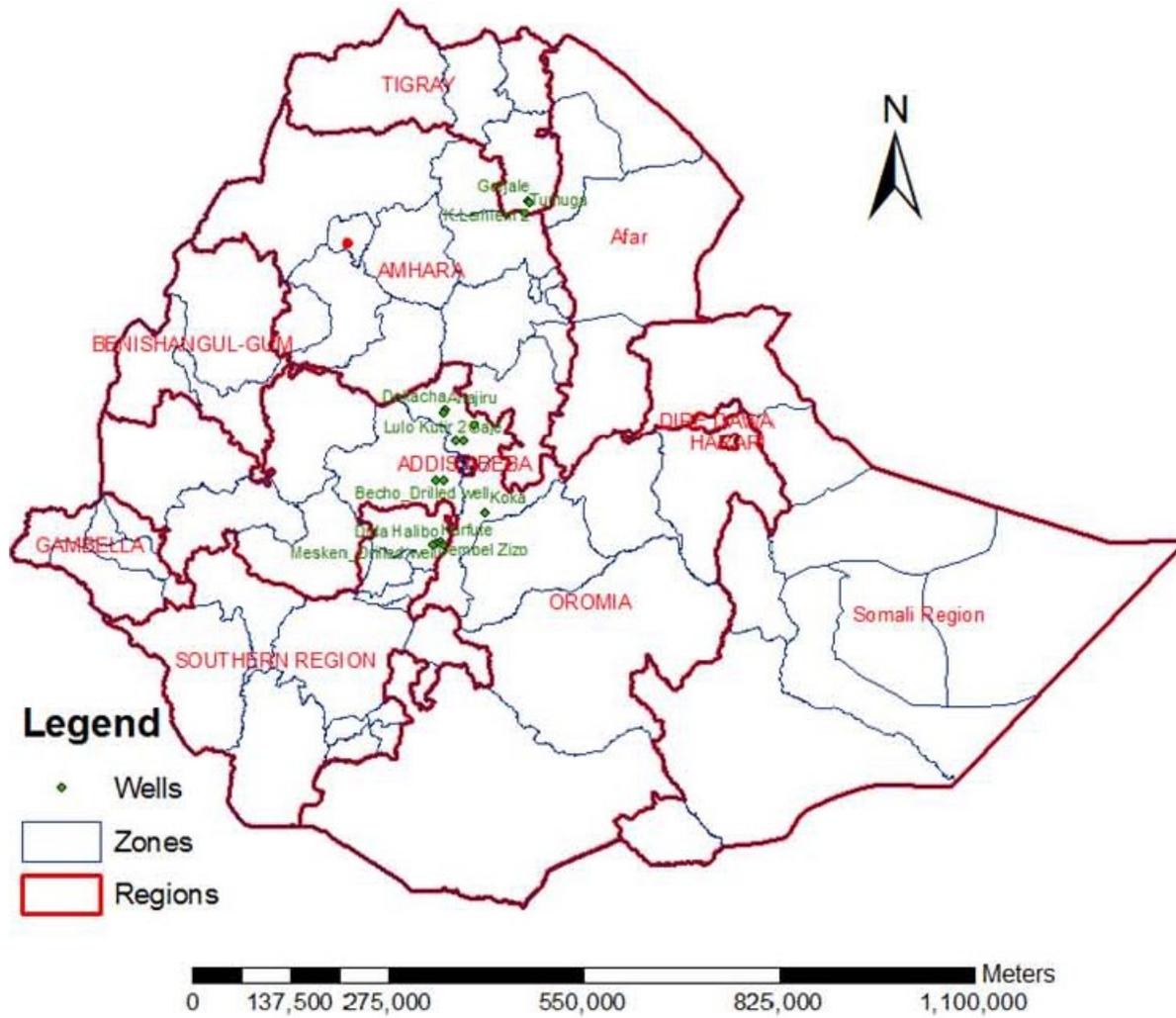
To get access to the abundant water resources stored in shallow aquifers there is a need for introducing low cost technologies for well development and water lifting. Local contexts vary considerably in terms of hydrogeology and farming systems, which require different solutions. To implement appropriate technologies, investments should be made in mapping groundwater, developing a national database, facilitating information sharing and developing a pool of skilled labor for well

drilling, reinforcement and pump maintenance. An improved institutional framework and groundwater policy are also required to coordinate efforts and facilitate mutual learning among different localities.

Even though manual drilling and low cost pumping technologies require relatively little initial investment, farmers and young entrepreneurs often lack the resources to access such technologies. Therefore, financial and credit institutions could play a major role in supporting this type of initiatives. Also, financial barriers could be lowered to support pump supply businesses, e.g. by reducing import taxes for smallholder irrigation equipment. Improving after-sales services, access to spare parts and extension services, and providing manuals in local languages could extend the life of pumps and prevent abandonment. Pump rental markets should also be explored (Evans et al 2012).

Hence, to tap from the high shallow groundwater potential and increase the productivity of smallholder farms in Ethiopian floodplains, a range of governmental, private and non-governmental organisations needs to be mobilized to provide the essential technical, financial and market support. Valuable initiatives have been made on a political and practical level, but increased support is needed to scale up solutions and provide access to the beneficiaries.

## 8. Map with locations visited flood wells



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**Colofon**

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The Tube Wells in Floodplains project, supported by Partners voor Water, aims to increase the productivity of marginally used floodplains by introducing a low-cost package of shallow tube well drilling techniques including pump technologies that can provide smallholder farmers with access to shallow groundwater.

The Spate Irrigation Network Foundation supports and promotes appropriate programmes and policies in flood based farming, exchanges information on the improvement of livelihoods through a range of interventions, assists in educational development and supports in the implementation and start-up of projects in Spate irrigation.

For more information: [www.spate-irrigation.org](http://www.spate-irrigation.org).



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