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Irrigation in Ethiopia, a Review

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Abstract

A critical review of recent studies on irrigation systems and developments in Ethiopia was conducted from the historical point of view up to the present and the future. This review discusses the Ethiopian irrigation based on the historical backgrounds, current conditions of development and its contributions to the national economy, challenges and opportunities, and future development perspectives. It is believed that irrigation practices were long been in use during ancient times with unspecified beginning period. However, Irrigation was not likely a driving force for the initiation of ancient civilization in Ethiopia. Since 1950's modern irrigation was introduced at the Rift Valley basin for productions of commercial crops. Government, donors and NGOs are investing in developing irrigation systems, especially on small-scale irrigations. As a result, irrigation is developing rapidly. However, its contribution to the national economy is not significant when compared to rain-fed agriculture. There is a scanty of detail study regarding water potentials and its developmental perspectives in the Ethiopian context as it lacks an agreed reports in common consensus. There should possibly be well-studied and documented reports in the field. It is evident that irrigation will play a significant role in the food security enhancement and economic development of Ethiopia, provided the efficient use of water is required.

Keywords: Small Scale Irrigation; Irrigation; Review; Ethiopia

1. Introduction

Ethiopia is a landlocked country, with a land area of 1.13 Million km2, found in Eastern Africa (Awulachew et al., 2007). Geographically, it is located in between the latitudes 5°N and 15°N, and longitudes 35°E and 45°E (yazew, 2005). The country is bordered by six countries, Eritrea in the North, Djibouti and Somalia in the East, Kenya and Somalia in the South, and Sudan and South Sudan in the West. Ethiopia's population is estimated at 85 million and is the second most populous country in Africa next to Nigeria (Awulachew et al., 2007). Most of the population in Ethiopia lives in highland areas, with 85 percent being rural and dependent on agriculture with a low level of productivity (Awulachew et al., 2007; MoA, 2011a; Bekele et al., 2012).

Agriculture is a mainstay of Ethiopian economy (World Bank, 2006; Makombe et al., 2011). The country is endowed with ample water resources with 12 river basins with an annual runoff volume of 122 Billion m3 of water and an estimated 2.6 - 2.65 Billion m3 of groundwater potential (Awulachew et al., 2007; Makombe et al., 2011; MoA, 2011a). Due to this Ethiopia is considered to be the water tower of Africa (Makombe et al., 2007).The cultivated agricultural land of Ethiopia currently under cultivation is about 12 million ha (MoA, 2011a). Moreover, Even if the potential and actual irrigated area is not precisely investigated (Belay and Bewket, 2013), estimates of irrigable land in Ethiopia vary between 1.5 and 4.3 Million hectares (Mha), averaged about 3.5 Mha (MoWR, 2001; Werfring, 2004; Awulachew et al., 2005; Makombe et al., 2011). However, it is surprising that the total land under irrigation now is estimated to be in the range between 160,000 - 200,000 hectares which is less than 5% of the country's irrigable land (Awulachew et al., 2005, 2007; World Bank, 2006; Makombe et al., 2007). However, MoA, (2011a) reported about 10 - 12% of the total irrigable potential are currently under production using traditional and modern irrigation schemes. Moreover, differences in irrigation potentials and actually irrigated lands, for example 3.7 Million ha and 197,000 ha according to Awlachew et al. (2007) and 3.5 Million ha and 626,116 ha as reported by Hagos et al. (2009) respectively, are indicated differences in this regard.

Hence, there is no consistent and reliable inventory and well-studied and documented with regards to water and irrigations related potentials in the Ethiopian context. This shows there is a scanty of detail study in the area. This knowledge goes important in such a way that the people and government who are living today become aware of what the people and governments in the past had done in the sector. This review is therefore important for understanding what was done in the past and what is going on now and the future in irrigation developments in Ethiopia.

2. Use of Irrigation Water in Ethiopia

Water is mankind's most vital and versatile natural resource (Nata et al., 2008) and has always played an essential role in Ethiopian society as it is an input to almost all production systems (MoWR, 2006). Water is also considered as an essential resource for irrigation. Irrigation can be defined as an artificial application of water to soil for the purpose of supplying the moisture essential in the plant root-zone to prevent stress that may cause reduced yield and/or poor quality of harvest of crops (Reddy, 2010). This is an intentional action made by human to apply water for growing crops, especially during dry seasons where there is a shortage of rainfall. Water applications to crop fields are of various types. The most commonly used and most ancient type is surface irrigation methods (FAO, 2002) through using gravity forces. This was used especially across river sides and it doesn't depend on mechanized equipments. Nowadays, modernized irrigation systems are mostly used which works based on the pressurized energy system (FAO, 2001). The sprinkler and drip irrigation systems are of this type of water application systems.

Irrigation in Ethiopia is considered as a basic strategy to alleviate poverty and hence food security. It is useful to transform the rain-fed agricultural system which depends on rainfall into the combined rain-fed and irrigation agricultural system. This is believed to be the most prominent way of sustainable development in the country. However, the development of irrigation practices in Ethiopia has to be investigated so as to seriously know the history of irrigation emergence and its subsequent developments.

Nata et al., (2007); Abraham et al., (2011) listed out the benefits of irrigation that includes; increase food production in arid and semi-arid regions, enhances food production, promotes economic growth and sustainable development, create employment opportunities, and improve living conditions of small-scale farmers. As a result, irrigation contributes to poverty reduction and protects the environment from degradation and pollution. Furthermore, it increases subsurface water levels and recharges groundwater. As a result, small, medium and large scale irrigation infrastructure needs to be developed in the country. This helps to produce export commodities that would earn foreign exchanges and provides raw materials to the local industries. Since, most of the irrigation development in Ethiopia is expressed through an expansion of small-scale irrigations. Medium and large scale irrigation developments are needed to be taken into consideration.

3. History of Irrigation in Ethiopia

Sulas et al., (2009) in the study conducted to investigate whether irrigation was a key factor in state formation and urban development in the ancient civilization of Axum, Northern Ethiopia, found non-sufficient information regardless of water managements of rain-fed agriculture. However, In Ethiopia, traditional irrigation was practiced before centuries (Bekele et al., 2012). Moreover, in the highlands of Ethiopia, irrigation practices have long been in use since ancient times for producing subsistence food crops (Awulachew et al., 2007; Bacha et al., 2011; MoA, 2011a). Different authors; Awlachew et al., (2007); Makombe et al., (2007); Hagos et al., (2009); Bacha et al., (2011) stressed that supplementary irrigation has been practiced by smallholder farmers of Ethiopia for centuries to solve their livelihood challenges.

Spate irrigation has also been used traditionally in Ethiopia (Mehari at al., 2011) particularly in Southern Tigray and in some semi-arid areas in Oromia region (MoA, 2011a). This irrigation system has been used for water harvesting from flush floods flooded from larger catchments at upper streams. These traditional irrigation systems were developed and managed through forming a water user's association for functions of construction, water allocation, operation and maintenance and were headed by individuals (Belay and Bewket, 2013). This association comprises up to 200 users grouped in to 20 to 30 groups of farmers who share a common main canal or its branches (MoA, 2011a). From the above discussions, the exact date when irrigation was started in Ethiopia remains uninvestigated regardless of routinely saying "irrigation was started in Ethiopia during ancient times" Awlachew et al ., (2007); Makombe et al ., (2007) ; Hagos et al ., (2009) ; Bacha et al ., (2011).

Modern irrigation, however, was started in the early 1950's by the bilateral agreement between the government of Ethiopia and the Dutch company jointly known as HVA-Ethiopia sugar cane plantation (MoA, 2011a; Bekele et al., 2012). Most of the traditional irrigated lands in Ethiopia are dominantly supplied by surface water sources, while ground water uses has just been started on a pilot basis in the East Amhara region (MoA, 2011a). According to MoA, (2011a) pressurized sprinkler irrigation system was once practiced in Fincha State Farm, Eastern Amhara, Southern Tigray and on some private farms in the Rift Valley. The Rift Valley is a place where modern irrigation in Ethiopia starts especially in the Awash River Basin at which adoption of pump-irrigation commences. Surface irrigation methods predominantly furrow irrigation and basin irrigation methods were practiced for cotton and wheat productions and for commercial fruits such as bananas respectively. Meanwhile, similar reports such as Awulachew et al., (2007) explained that irrigated agriculture was started in Ethiopia in the

upper Awash Valley with the objective of producing industrial crops as sugarcane, cotton and horticultural crops on a large-scale basis, explained in a remarkable emergence of irrigation development and establishment of agro-industrial centers. This was due to taking an advantage of the construction of Koka dam aimed as a reservoir irrigation water supply, flood control and hydropower generation. During the middle 1970s, windmills and hand pumps were introduced to lift water from groundwater for drinking water supply, domestic and gardening purposes (MoA, 2011a).

According to the Ministry of Agriculture, in Ethiopia, there were modern water storage and water management systems for irrigation purposes. This includes water diversion schemes, water storage dams, micro irrigation systems, rainwater harvesting and shallow groundwater harvesting techniques. These systems make use of different water drawing irrigation technologies for lifting, conveying and applying irrigation water for irrigation uses. Night water storage facilities, Treadle pumps for lifting water, smallholder drip systems and micro-sprinklers for irrigation application are used among others (MoA, 2011a).

4. Ways of Irrigation Development in Ethiopia

Makombe et al., (2011) noted that irrigation development is a key for sustainable and reliable agricultural development which leads to overall development in Ethiopia. Irrigated agriculture is being practiced under smallholders, medium and large scale farming. Many authors such as Awlachew et al., (2007); Makomb et al., (2007); Hagos et al., (2009); Bacha et al., (2011) were used government based irrigation schemes classification systems for their description during their studies. According to Ministry of Water Resources of Ethiopia (MoWR, 2002), irrigation development in Ethiopia is classified based on the size of the command area, in three types (Table 1).

1. Small-scale irrigation systems (<200 hectares (ha)),
2. Medium-scale irrigation systems (200-3,000 ha),
3. Large-scale irrigation systems (>3,000 ha).

This irrigation classification system is the most common in Ethiopia. Accordingly, 46% of proposed irrigation development are in the small-scale irrigation category (Makombe et al., 2011).

Table 1; Summary of typologies of irrigation schemes in Ethiopia (source: Hagos et al., 2009

Typology	Size of scheme (ha)	Infrastructures	Water management scheme (ha)
Small-scale	<200	Fixed or improved water control and diversion structures made of local materials.	Water users' association or irrigation cooperatives. Local water users' association
Medium-scale	200-3000	Fixed or improved water control and diversion structures.	Water users' association/ irrigation. cooperatives or state
Large-scale	>3000	Fixed or improved water control and diversion structures.	Mostly state enterprises

According to Makombe et al., (2011) the irrigation development in Ethiopia is also classified based on the uses of a mix of the history of establishment, management system and the nature of the structures as follows:

1) Traditional schemes: These are small-scale irrigation systems which usually use diversion weirs made from local material and needs annual maintenance. The canals are usually earthen and the schemes are managed by the community.

2) Modern schemes: These are small-scale irrigation systems with more permanent diversion weirs made from concrete that don't require annual maintenance. They are mostly community-managed and the primary and secondary channels are made of concrete.

3) Public: These are large-scale operations constructed and managed by the government. Sometimes these schemes support out-growers (smallholder farmers who have farms in the vicinity of the large–scale schemes).

4) Private: These are privately owned systems in mechanized farms which need a highly intensive operation.

These two irrigation classification systems are the most used classification system in Ethiopia among others.

This systematic classification has been used by different stakeholders in the sector for efficient planning and utilization of irrigation projects.

5. Irrigation Developments in Ethiopia

Irrigation development is vital to the sustainable and reliable agricultural developments in Ethiopia. Subsistence dominated smallholder farmers' economy can be improved through the use of irrigation in the Ethiopian agriculture (MoA, 2011b). Similarly, make use of irrigation agriculture is going to be a means for increased agricultural production to meet the growing food demands of rapid population growth. Irrigation development in Ethiopia can be considered as a cornerstone of food security and poverty reduction tool as it has a power to stimulate economic growth and rural developments (Hagos et al., 2009). As a result, irrigation infrastructures are increasing year after year, which show country wide positive development implications and experiences in small and large scale irrigation schemes. In Ethiopia, farm size per household is 0.5ha and the irrigated land per households' ranges from 0.25 ha - 0.5 ha in the Ethiopian context (MoA, 2011a). As a result, individual land holdings per households are too small to feed the household. With this limited landholdings, increasing food demands of the population depends on either one or a combination of increasing agricultural yield, increasing the area of arable land, and increasing cropping intensity by growing two or three crops per year using irrigation (MoA, 2011a).

On the other way, Irrigation development in Ethiopia is in its infancy stage (MoA, 2011a). The Ethiopian government is therefore pursuing plans and programs to develop irrigation in an effort to substantially reduce poverty and create an atmosphere for social change. As a result, the Ethiopian average rate of irrigation development for the last 12 years was about 1,090 - 1,150 ha/year (Nata et al., 2008; Bekele et al., 2012). In Ethiopia, only 10% of the estimated potential irrigable land is actually irrigated (Gebremedhin and Pedon, 2002) and 2% of cultivated lands are irrigated (MoWR, 2001). Similarly, irrigated agriculture comprises only 3% of the total national food production (Bacha et al., 2011). That is why; irrigated agriculture is far from satisfactory despite of considerable investment, public interest, and strategic support of the government.

Belay and Bewket, (2013) explained that irrigation water is critical to poverty alleviation through increased production in rural areas so as to improve food security and rural livelihoods. Smallholder irrigation has recently received significant focus from local governments to enable farmers to cultivate crops twice or more per year. Bacha et al. (2011) in the study of the impact of small-scale irrigation on household poverty in central Ethiopia, reported that land productivity, asset ownership, credit utilization, extension support, resilience to poverty, mean off-farm income, and mean food consumption and expenditure on food and non-food assets were significantly higher for irrigators than non-irrigators.

Irrigation development is taking place through the use of government budgets, donor programs and NGOs. However, As compared to its potential and rain-fed farming, contribution of irrigation to the national economy is quite limited which contributes about 2.5% of the overall GDP (Hagos et al., 2009; MoA, 2011a). Moreover, the existing irrigation development in Ethiopia, as compared to the irrigation potential the country has, is not significant (MoA, 2011b). Thus, irrigation has to play significant contribution in mitigating food insecurity and hence poverty reduction.

6. Drivers of Irrigation Development in Ethiopia

Small scale households are the main units for development in Ethiopia. All the irrigation development partners work for the betterment of these households. The Ethiopian Agricultural Development Led Industrialization (ADLI) policies and its driven strategies make use of favourable conditions for the irrigation development. Most of the irrigation partners are from international communities up to localities that have significant contributions towards food security and poverty reductions at households and national levels. According to the Ministry of Agriculture (MoA, 2011a); World Bank, CIDA, EU, AfDB, US Government, Japan, UNDP, UNICEF, World Vision, Plan International, Menchen fur Menchen, Care Ethiopia, Concern Ethiopia, Water Action, Water Aid Ethiopia, Oxfam, Lutheran World Federation, FHI/E, IFAD, JICA, SIDA, Irish Aid, CRS, GIZ, SOS Sahel, CIDA are among the international partners towards irrigation developments in Ethiopia. Meanwhile, Ethiopian Orthodox church, Ethiopian Evangelical Church, OSHO, ORDA, REST etcetera are mentioned as local NGOs participating in the sector.

7. Challenges and Opportunities of Irrigation in Ethiopia

According to the MoWIE, (2013) and MoA, (2011a) the main challenges and opportunities for the development of irrigation in Ethiopia is listed hereunder. These narrations are provided for explanations of small scale irrigation schemes. More on this issue can be found at MoA, (2011a).

7.1. Challenges

These challenges can be explained as technical constraints and knowledge gaps are identified (1) inadequate awareness of irrigation water management as in irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques, operation and maintenance of irrigation facilities, (2) Inadequate knowledge on improved and diversified irrigation agronomic practices, (3) Shortage of basic technical knowledge on irrigation pumps, drip irrigation system, sprinkler irrigations, surface and spate irrigation methods (4) Scheme based approach rather than area/catchments based approach for the development of SSI Schemes,(5) inadequate baseline data and information on the development of water resources, (6) lack of experience in design, construction and supervision of quality irrigation projects, (7) low productivity of existing irrigation schemes, (8) inadequate community involvement and consultation in scheme planning, construction and implementation of irrigation development, (9) Poor economic background of users for irrigation infrastructure development, to access irrigation technologies and agricultural inputs, where the price increment is not affordable to farmers.

7.2. Opportunities

The basic opportunistic considerations regarding irrigation developments in Ethiopia are (1) emphasis and priorities are given to irrigation in the growth and transformation plan of the country, (2) indigenous knowledge and introduction of promising household water harvesting and micro-irrigation technologies, (3) government's strong political commitment and encouragement to private sector and public enterprises involvement in irrigation development, (4) abundant water resources, climate and land suitability, (4) availability of inexpensive labour, (5) availability of suitable lands for irrigation developments especially at arid areas of the country.

8. Future Irrigation Programs in Ethiopia

The Ethiopian Irrigation Development Plan (IDP) emphasizes the development of small-scale irrigation systems through giving highest priority for capacity-building in the study, design, and implementation of irrigation projects. Increasing emphasis will also be given to the development of large and medium-scale irrigation schemes. Ethiopia has designed a Water Sector Development Programme (MoWR, 2002). Accordingly, new irrigation works will be undertaken to develop a total of 274,612 ha of farmland under the irrigation development plan by the federal government and regional governments for large and medium scale irrigation developments. By the end of the water sector development program (WSDP), the total area under irrigation will be 5.1Million ha (MoWR, 2002). However, due considerations should be given during expansion of irrigation infrastructures. Irrigation can have adverse effects on environment and public health, if it is not properly managed (Abraham et al., 2011).

9. Conclusion

This work has thoroughly reviewed the Ethiopian irrigation on the basis of historical backgrounds, current conditions of development and its contributions to the national economy, challenges and opportunities, and future development perspectives. The authors didn't found evidence that the ancient civilization in Ethiopia was actually existence of irrigation practices. However, it is believed that irrigation was practiced during ancient times in Ethiopia even if its exact date of emergence is unknown. Ancient use of irrigation water was through use of surface method irrigation methods and spate irrigation types.

Modern irrigation was started at the Awash River basin in the Rift Valley with bilateral cooperation of Ethiopia and Dutch company. This was started during the 1950s for the productions of commercial crops such as sugar cane and cotton. Irrigation of these crops was applied by surface irrigation methods and less efficient pressurized irrigation systems.

During reviewing the irrigation in Ethiopia, different literatures reports differently regarding the amount irrigation water resources as irrigation potentials, area irrigated right now and the like. This implies that irrigation water resource potentials in Ethiopia are not well-studied and documented. Hence, this needs to have a very detailed study that leads to a common consensus among researchers.

Nowadays, the policies and strategies of Ethiopia strongly supports the irrigation developments especially the small scale irrigation (SSI) through the Water Sector Development Programs (WSDP) and Ethiopian Irrigation Development Plan (IDP). This irrigation development is mainly expressed in the development of small scale irrigation (SSI) schemes by governments, donors and NGOs. Irrigation is believed as a key for food security and poverty reduction in Ethiopia. As a result, developments in the Ethiopian irrigation system have shown great advancements so as to assure Ethiopian livelihoods especially in the rural areas. However, the contribution of irrigation to the national economy as compared to its potentials is insignificant. This indicates more investments on the area have paramount importance for the development of the country. Generally, the government and

peoples of Ethiopia believes that irrigation can play a significant role for food security enhancement and economic growth. Therefore, intensive investments should be operated in the sector by governmental, non-governmental and privates investors especially in medium and large scale irrigation developments.

References

Abraham Bairu Gebrehiwot, Nata Tadesse, K. Bheemalingeswara, Mokennen Haileselassie, (2011), Suitability of Groundwater Quality for Irrigation: A Case Study on Hand Dug Wells in Hantebet Catchment, Tigray, Northern Ethiopia. *Journal of American Science*, **7**(8):191-199.

Awulachew, S. B., Yilma, A. D.,Loulseged, M., Loiskandl, W., Ayana, M., Alamirew, T., (2007), Water Resources and Irrigation Development in Ethiopia. Colombo, Sri Lanka: International Water Management Institute. 78p. (Working Paper 123).

Awulachew, S. B.; Merry, D. J.; Kamara, A. B.; van Koppen, B.; Penning de Vries, F.; Boelee, E.; Makombe, G., (2005), Experiences and opportunities for promoting small-scale/micro irrigation and rainwater harvesting for food security in Ethiopia. Colombo, Sri Lanka: International Water Management Institute (IWMI). 91p. (IWMI Working Paper 98).

Bacha Dereje, Regasa Namara, Ayalneh Bogale and Abonesh Tesfaye, (2011), Impact of Small-Scale Irrigation on Household Poverty: Empirical Evidence from the Ambo District in Ethiopia, *Irrigation and Drainage*, **60**: 1–10.

Bekele Yeshitela, NataTadesse and Bheemalingswara Konka, (2012), Preliminary Study on the Impact of Water Quality and Irrigation Practices on Soil Salinity and Crop Production, Gergera Watershed, Atsbi-Wonberta, Tigray,Northern Ethiopia, *MEJS*, Volume **4** (1):29-46.

Belay Mehretie and Woldeamlak Bewket, (2013), Traditional Irrigation and Water Management Practices in Highland Ethiopia: Case Study in Dangila Woreda, *Irrigation and Drainage*, **62**: 435– 448.

FAO (Food and Agriculture Organization of the United Nations), (2001), Irrigation Manual: Planning, Development Monitoring and Evaluation of Irrigated Agriculture with Farmer Participation, Volume III, Module 8.

FAO (Food and Agriculture Organization of the United Nations), (2002), Irrigation Manual: Planning, Development Monitoring and Evaluation of Irrigated Agriculture with Farmer Participation, Volume II, Module 7.

Gebremedhin Berhanu, Pedon D., (2002), Policies and institutions to enhance the impact of irrigation development in mixed crop–livestock system. In Integrated Water and Land Management Research and Capacity Building Priorities for Ethiopia , *Proceedings of MoWR/EARO/IWMI/ILRI* International Workshop held at ILRI, Addis Ababa, Ethiopia, 2–4 December;168–184.

Hagos, F., Makombe, G., Namara, R. E., Awulachew, S. B., (2009), Importance of irrigated agriculture to the Ethiopian economy: Capturing the direct net benefits of irrigation. Colombo, Sri Lanka: International Water Management Institute. 37p. (IWMI Research Report 128).

Makombe, G.; Kelemework, D.; Aredo, D., (2007), A comparative analysis of rainfed and irrigated agricultural production in Ethiopia. *Irrigation and Drainage Systems* **21**: 35-44.

Makombe, G.; Namara, R.; Hagos, F.; Awulachew, S. B.; Ayana, M.; Bossio, D., (2011), A comparative analysis of the technical efficiency of rain-fed and smallholder irrigation in Ethiopia. Colombo, Sri Lanka: International Water Management Institute. 37p. (IWMI Working Paper 143).

Mehari Abraham, Frank Van Steenbergen and Bart Schultz, (2011), Modernization of Spate Irrigated Agriculture: A New Approach, *Irrig. and Drain*. **60**: 163–173.

MoA (Ministry of Agriculture) Natural Resources Management Directorates, (2011a), Small-Scale Irrigation Situation Analysis and Capacity Needs Assessment, Addis Ababa, Ethiopia.

MoA (Ministry of Agriculture) Natural Resources Sector, (2011b), Small-Scale Irrigation Capacity Building Strategy for Ethiopia, Addis Ababa, Ethiopia.

MoWIE (Ministry of Water, Irrigation and Energy), (2013), Water Resources of Ethiopia; The National and International Perspective, Awareness creation Program prepared for Public Relation officials, Addis Ababa, Ethiopia.

MoWR (Ministry of Water Resources), (2001), Irrigation Development Strategy (Component of the Water Sector Development Strategy). Draft Report. Addis Ababa, Ethiopia.

MoWR (Ministry of Water Resources), (2002), Water Sector Development Programme 2002–2016. Irrigation Development Program, Main report. MoWR, Addis Ababa, Ethiopia, 142pp.

MoWR (Ministry of Water Resources), (2006), Ethiopia: Managing Water Resources to Maximize Sustainable Growth, Country Water Resources Assistance Strategy, a World Bank Water Resources Assistance Strategy for Ethiopia, Addis Ababa, 91p.

Nata, Tadesse and Asmelash, Berhane, (2007), Recharging Practices for the enhancement of hand dug wells discharge in Debre Kidane watershed, North Ethiopia. *4th International Work Shop on Water Management and Irrigation*: Focus on groundwater. Mekelle University, Mekelle, Ethiopia.

Nata Tadesse, Asmelash Berhane and Bheemalingeswara K., (2008), Initiatives, Opportunities and Challenges in Shallow Groundwater Utilization: a Case Study from Debrekidane Watershed, Hawzien Woreda, Tigray Region, Northern Ethiopia, Agricultural Engineering International: the *CIGR Ejourna l*. Manuscript LW 08 008. Vol. X.

Reddy R.N., (2010), Irrigation Engineering, Gene-Tech Books, New Delhi - 110 002.

Sulas Federica, Marco Madella and Charles French, (2009), State formation and water resources management in the Horn of Africa: the Aksumite Kingdom of the northern Ethiopian highlands, *World Archaeology*, **41**:1, 2-15.

Werfring, A. (2004), Typology of irrigation in Ethiopia. A thesis submitted to the University of Natural Resources and Applied Life Sciences, Vienna. Institute of Hydraulics and Rural Water Management, in partial fulfillment of the degree of Diplomingeieur.

World Bank, (2006), Ethiopia: Managing water resources to maximize sustainable growth. A World Bank water resources assistance strategy for Ethiopia. The World Bank Agriculture and Rural Development Department. Report No. 36000-ET. Washington, DC, USA.

Yazew E. (2005), Development and management of irrigated lands in Tigray, Ethiopia. PhD thesis, UNESCO-IHE Institute for Water Education, Delft, the Netherlands, 265pp.

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