

# **WATER-CENTERED GROWTH CHALLENGES, INNOVATIONS AND INTERVENTIONS IN ETHIOPIA**

*Seleshi Bekele Awulachew*

*Senior Researcher, International Water Management Institute, East Africa and Nile Basin Office, Addis Ababa, Ethiopia; Leader, Water Resources Think Tank Group*

## **Abstract**

Ethiopia's economy and majority of the people's livelihoods are dependent on agriculture. To develop the socio-economy of Ethiopia and eradicate poverty, the policy and interventions should focus on agriculture as an entry point. In line with this, the government, bilateral and multilateral donors, NGOs and various institutions share the concepts and priorities identified in the "Plan for Accelerated and Sustained Development to End Poverty (PASDEP)." There are key challenges that need to be strongly addressed on transforming agriculture by overcoming a multitude of problems including biophysical and water management issues to help achieve the targets of PASDEP and sustainable socioeconomic growth in Ethiopia. This particular paper aimed at addressing the water management challenges that Ethiopia has faced in the past and is facing today, and to stimulate ideas on how to manage water resources to meet the growing needs for agricultural products, to help reduce poverty and food insecurity, and to show how water can be used as an important entry point to transform its socio-economy and contribute to sustainable development and the environment. The issues discussed will focus on innovations, policies and technologies that enable better investment and management decisions in water use, particularly focusing on agriculture and irrigation but also briefly looking into other water-related subsectors such as hydropower, water supply, watershed, drought and flood management as well as other

biophysical aspects. It has also been attempted to make the paper suitable for decision-makers rather than scientists, in order to raise useful ideas for dialogue and further discussions, studies and researches. The paper, therefore, does not claim exhaustiveness. The target audiences of this paper are the people who make the investment and management decisions in water and water management for agriculture, and other subsectors - agricultural producers, water managers, investors, policymakers and civil society. The paper has benefited from the review of key policy and strategy documents of Ethiopia, outputs of various outcomes of research, civil society meetings and workshops, data and information available in government institutions, and global knowledge. The key major issues that are discussed in the paper include the following:

- Socioeconomic development challenges of Ethiopia, viewed from a water resources perspective.
- The water resources endowment, development extent, potentials and economic/socioeconomic development linkages
- Water-related innovations and agriculture
- Water-related interventions in various agro-ecologies
- Policy and strategy actions needed

This paper should also be viewed with other components such as river basin growth pole/corridor concept,

institutional reform and research capacity building. It focuses on analyzing key problems and associated interventions, and can be applicable in the contexts of the current situation and the future possible reform under growth zones that can be taken as plausible pathways for development.

## 1. Introduction

Civilization of human being and socio-economic development are strongly associated with the capacity to manage and utilize water for beneficial purposes such as agriculture, power production, clean water supply, etc and cope with the negative externalities of impact of water such as flood, drought, contaminations, etc. Water is closely linked with hunger, poverty and health.

Some seventy percent of the 600 million “\$-poor” and the 200 million malnourished people in Africa live in rural areas, with agriculture as their sole or primary source of food and income. Agriculture is their only way out of poverty. Soil nutrient loss and lack of access to safe and reliable water are the chief biophysical factors limiting small farm production and therefore critical to any poverty reduction strategy for the rural poor. Ethiopia is strongly challenged with water management, and unable to enhance the positive role of water and mitigate the negative externalities, and as such no time in its history able to manage water fully and effectively to accelerate its development. The current situation is encouraging and excellent start particularly since 2003.

The key and major issues that are discussed in the paper include:

- The key socio-economic development challenge of Ethiopia, viewing from water angle

This particular paper aimed at the water management challenges that Ethiopia has faced in the past and today, stimulate ideas on how to manage water resources to meet the growing needs for agricultural products, to help reduce poverty and food insecurity, and to show how water can be used as important entry point to transform its socio-economy and contribute to sustainable development and environment.

The issues discussed will focus on innovations, policies and technologies that enable better investment and management decisions in water particularly focusing on agriculture and irrigation but also briefly looks in to other water related sub-sectors such as hydropower, water supply, watershed, drought and flood management as well as other biophysical aspects.

It is also tried to make the paper suitable to decision makers rather than scientists, to raise useful ideas for dialogue and further discussions, studies and researches. The paper therefore does not claim exhaustiveness. The target audiences of this are the people who make the investment and management decisions in water and water management for agriculture and other sub sectors—agricultural producers, water managers, investors, policymakers, and civil society. The paper has benefited from the review of key policy and strategy documents of Ethiopia, outputs of various outcomes of civil society meetings and workshop, data and information available in government institutions and global knowledge.

- The water resources endowment, development extent, potentials and economic/socio-economic development linkage
- Water related innovations and agriculture

- Water related interventions in various agro-ecologies
- Policy actions needed

This paper should also be viewed with other components such as river basin growth pole/corridor concept, institutional reform and research capacity building. It focuses on analyzing key problems and associated interventions, and can be applicable in the contexts of the current situation and the future possible reform under growth zones that can be taken as plausible pathways for development.

## **2. Water and development challenge of Ethiopia**

The main development objective of the Ethiopian Government is poverty eradication. Hence, the country's development policies and strategies are geared towards this end (MOFED: PASDEP 2006).

Ethiopia's economy and majority of people's livelihood is dependent on Agriculture. To develop the socio-economy of Ethiopia and eradicate poverty the policy and interventions should focus on Agriculture as entry point. This is a correct, clear and precise direction that the current government has put forward. There are key challenges that need to be strongly addressed on transforming agriculture by overcoming multitude of problems including biophysical and water management issues to help attainment of PASDEP and sustainable socio-economic growth of Ethiopia.

It is essential to think differently about water in order to achieve a multiple goal. This will have profound effect towards sustainable development through mitigation of rainfall variability, ensuring productivity and production growth, food security, eradication of poverty, sustaining development, reversing degradation

and acceleration of growth. The contexts of these challenges are briefly discussed in the following paragraphs with the intention of recapping their importance.

### **2.1 Poverty is a Vicious Cycle in Ethiopia**

The poverty situation in Ethiopia is in a vicious cycle, and requires key entry points for intervention. The following flow of recurrences reflects how poverty is linked to and aggravated by various factors.

Population growth (leads to aggravate) → agriculture and livestock into marginal land and deforestation → land & water degradation → poor productivity, food insecurity → deepening poverty → poor health, malnutrition → inability to invest in maintaining or improving land productivity → further degradation and population growth, etc, and these are further aggravated by shocks of climate variability, conflict/war, etc. How to transform this “vicious cycle” in to a “virtuous cycle” is the key question that needs to be addressed.

### **2.2 Unmitigated rainfall and hydrological variability**

Unmitigated hydro-meteorological variability currently costs the economy over one-third of its growth potential, see for example Figure 1. PASDEP's analysis also shows for example, the 2002/2003 drought has cost Ethiopia with negative 3.3% real GDP growth, while the following years were positive 11.9% and 10.6%, which slowed down the growth averaged over the three years at 6.4% only. The structure of the Ethiopian agricultural economy, and hence the overall socio-economic development is heavily reliant on rain fed subsistence agriculture, which makes it particularly vulnerable to this variability. Unmitigated variability is reflected not only in terms of drought

and its consequences, but also in terms of prolonged dry spells, seasonality and floods. Ethiopia's extremely low levels of hydraulic infrastructure and limited water resources management capacity undermine attempts to

In order to transform agriculture as a basis for industry and eradication of poverty and wealth creation, it is important to understand the critical issues that can facilitate the process and identify hindering factors to mitigate the effects. Agriculture should grow both in productivity (kg of yield per hectare of land, water or any other

manage variability. It is not an overstatement to mention that Ethiopia's economic performance virtually hostage to its hydrology and the cause for deepening poverty.

Input) and production (volume of total produce). A number of factors are affecting these. The key variables for these are seed varieties, soil fertility and agricultural water management (AWM). Additionally, other factors such as market, infrastructure, institutions, etc also come to in the equations.

**Impact of rainfall variability on GDP and Agricultural GDP growth**

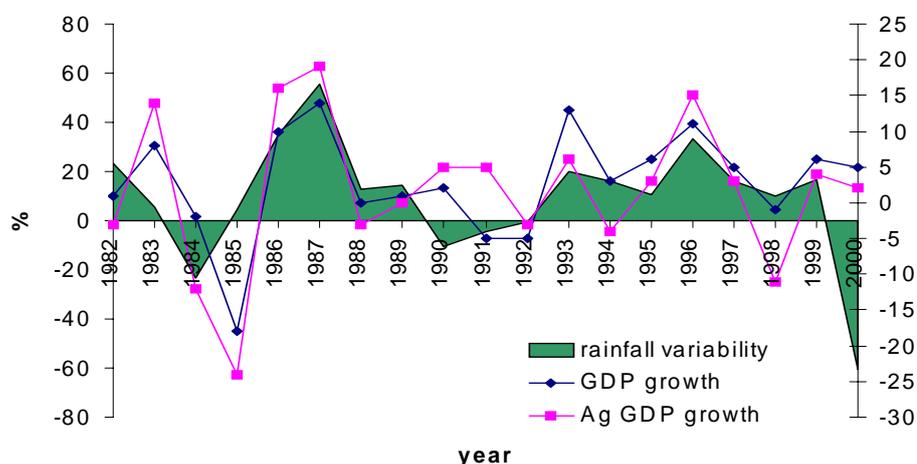


Figure 1: Impact of Rainfall variability on GDP and AG GDP

### 2.3 Low Productivity of Agriculture

While past efforts (prior to the 2002/3 drought) mainly focusing on the first two key variables and AWM was given low priority. The low priority context of the past is evidenced by low investment in irrigation including related sectors such as water supply, hydropower, etc. However, in the recent past few years, the trend has completely changed and water has been recognized as a key factor in Ethiopian agriculture and socio-

Economic development and actions are clearly visible beyond the words.

Agricultural productivity is low and stagnant in the whole of Sub-Saharan Africa, and it is not particularly peculiar to Ethiopia. Figures 2 (World Bank, 2003) and Figure 3 (Molden 2007) show this evidence. Sub-Saharan Africa never benefited from the Green Revolution of the 1960s and 1970s with high-yielding crop varieties, irrigation, fertilizers, and pest management. The result is extremely low cereal yields (oscillating  $\approx$  1 ton/hectare) and merely 5% of agricultural land under irrigation. South and Southeast Asia, on the contrary, were at the heart of the Green Revolution, with higher yields (at least

twice as high as in sub-Saharan Africa; and large irrigation withdrawals amounting to 60% of agricultural water use Rockstroem et al (2007).

SSA has yet to close the agricultural product gap as the Asia and Latin America have done through the green revolution, so does need Ethiopia, may

be at a better speed. Ethiopia needs a higher poverty escaping velocity because of its rapidly growing population, and the opportunity of the focus for development that exist today. Therefore, there are tremendous opportunities to improve productivity of agriculture.

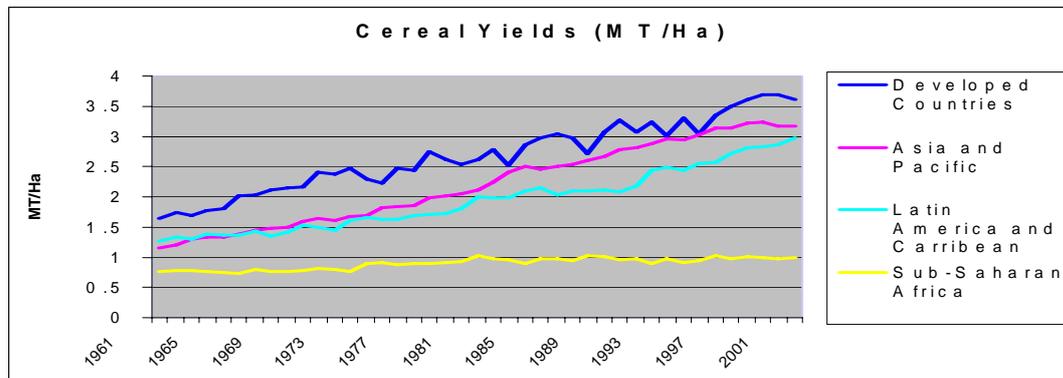


Figure 2: Comparative cereal yield of SSA

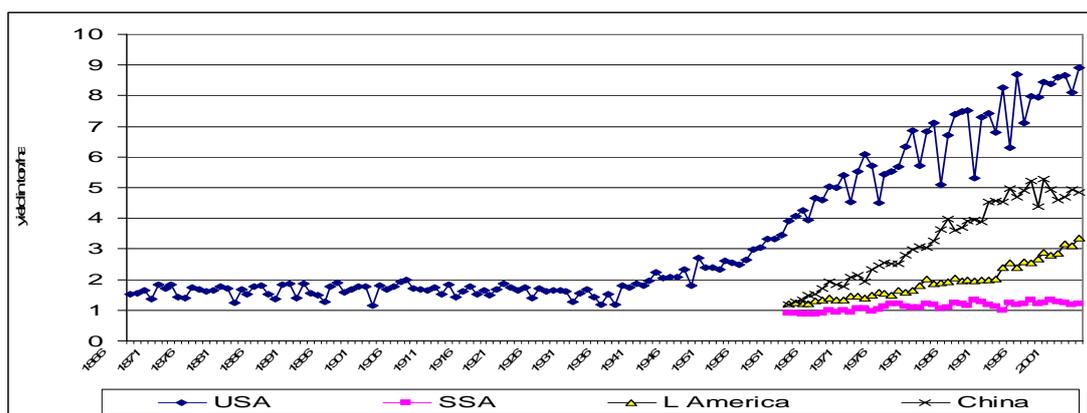
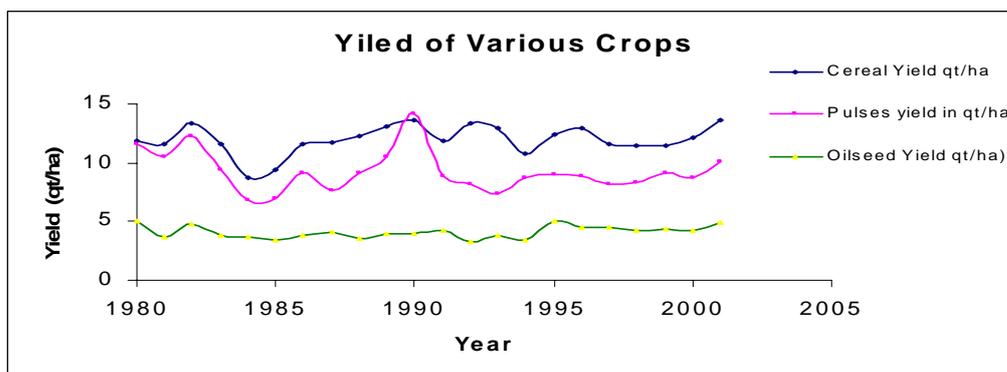


Figure 3: Comparative maize yield

It is also important to look in to productivity of agriculture in Ethiopia separately. The data until, 2001 for cereal yield in Ethiopia, does not show any difference with the SSA, and it was low and stagnant, see Figure 4. Leaving the 2002/2003 production that was hit by drought, Ethiopia is improving productivity and production since 2004. Based on PASDEP data Figure 5 shows this evidence. The

figure also shows the determined plan to improve productivity, which enables to reach the current level of Latin America. Based on these evidences, it is further possible to increase production and productivity, but one has to be seriously careful how to overcome the 2002/3 type problem and the use and management of rainfall and water.



a) Low productivity of agriculture

Growth Attributes (up to 2001)	Type of crop		
	Cereal	Pulses	Oil seeds
Average annual production growth	0.74	0.6	0.48
Growth attributed to land expansion	0.57	0.45	0.38
Growth attributed to yield increase	0.17	0.15	0.1

b) Productivity growths for various crops and growth attributes

Figure 4 a) and b) Productivity of agriculture

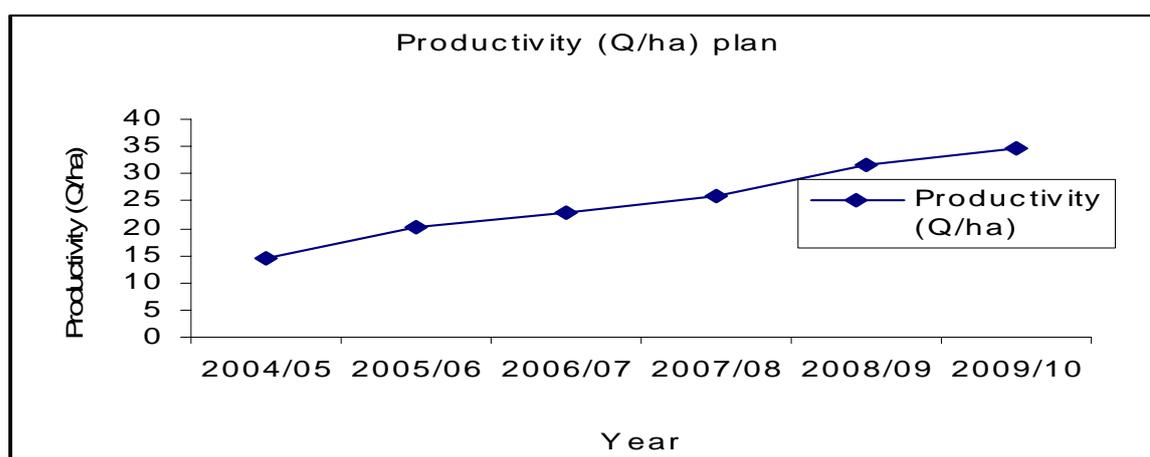


Figure 5: Estimated productivity during PASDEP period

## 2.4 Food Insecurity

Food deficiency and famine occurrences in the country are claimed to be as a result of the erratic nature of rainfall or drought. Ethiopia has faced three large-scale drought induced food shortage and famine in recent times (i.e. in 1972/73, 1983/84, 2002/03). The tragedies of the earlier two have claimed thousands of lives (See figure 6 below based on Ethiopia calendar). In 2002/03 about 15 million people (over 20% of the total population) were under food aid need. Both number of population and proportion

of population affected by drought and flood are with increasing trend. Figure 6 and 7 show the drought and disaster affected population, proportion and the amount of imported food aid.

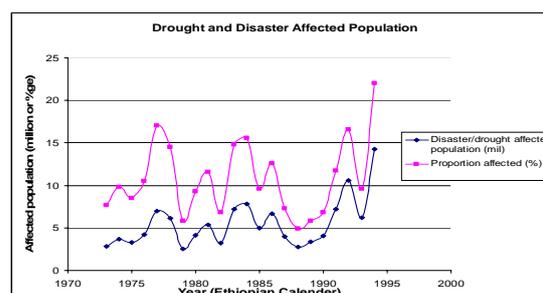


Figure 6: Drought and Disaster Affected Populations during the last decade

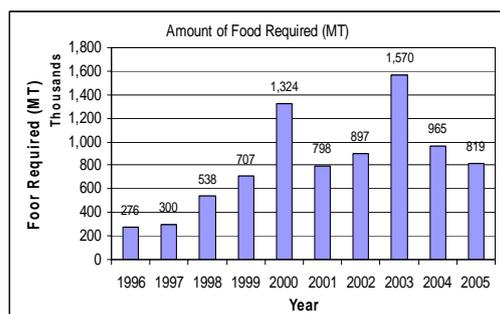


Figure 7: Amount of food aid imported (Data Source: DPPC)

## 2.5 Eradication of Poverty, Enhancing and Sustaining Development

Eradication of poverty on sustainable basis is not simple. In today's competitive world it requires significant investment in various sectors. The Millennium Development Goals (MDGs) pledge, among others, to reduce the number of chronically hungry people by half by 2015. Ethiopia has also put forward a target of reaching middle income countries in 20 years. Achieving these goals is major challenge and requires substantial investment in the smallholder agricultural sector, which is the key occupation for the majority of the poor.

Even for investments 'only' in 'water', we must recognize that to make effective decisions on investments in agriculture, increase of five different types of 'capital' must be considered: natural capital, social capital, human capital, financial capital, and physical capital. For successful and sustainable agriculture, access to all five capitals is needed in reasonable amounts. However, some of these capitals may already be available while one or two others are in short supply. Opportunities for successful investments can be created by increasing the one or two essential capitals that are most lacking. Direct

and indirect investments can increase the capitals that are in short supply. Since augmenting 'natural capital' requires quite different actions from augmenting 'human capital', and the same for the other capitals, one needs to distinguish the decisions that need to be taken to increase those capitals that are most needed.

When all capitals are reasonably available, production processes are more efficient and hence yield a higher return on investments than when one or more capitals are lacking. This is an important consideration for investment decisions, and as a policy feed back to Ethiopian policy.

Rural development policy and strategy recognizes the abundance and availability of *human capital* in the form of labor and *natural capital* particularly land and to some extent water. We have to clearly reflect that Ethiopia is doing very well in increasing the human capital, evidenced by expansion of education at all levels, that can also support the mass of the less skilled agricultural labor in the rural areas. No other recent evidences in SSA that matches Ethiopia's expansion of higher education. Despite over all low budget, Ethiopia is allocating significant share of its budget to agriculture and water development (still more can be done), hence improving its financial capital flowing to the sector. It has to continue investing in the two sectors.

Although there are strategies and encouraging results achieved in recent years, the *physical capital* and infrastructure of Ethiopia are far from adequate. Similarly, the *social capital* needs transformation. Ethiopian people, particularly, in the highly vulnerable areas have developed dependency syndrome on external/foreign aid. Philosophically, dependence on aid, and not having once own reliable solution, are one of

the causes for remaining in poverty for long and the cause to retarding escaping velocity out of poverty. The culture, religion, population dynamics, settlement character, etc should be transformed to assist development not hinder development and continue to be obstacle of progress.

Critical factors therefore are lack of physical capital, financial capital and natural capital (problem of matching the existing natural capital with the population settlement, as most people live in degraded areas while natural capital endowments such as fertile land and water are placed at far places from settlement). The other's such as social and human capitals development should continue and can reach reasonable stage in near future.

## **2.6 Challenges of Resources Degradation and Sustainability**

Various studies such as (Hurni, 1993) and other land use and degradation papers show that soil losses in cultivated land caused by water, through sheet and rill erosion, reach alarming levels of up to 100–200 Mt ha/yr, affecting 50 per cent of the agricultural areas. Population densities and herd sizes are the highest in Africa, and continue to grow rapidly putting a severe pressure on the land. Currently, crop yields and livestock production are among the lowest levels in Africa, leaving over 40% of Ethiopian's poor. Hence, the urgent necessity to reverse this trend and assess the impact of water erosion hazard in Ethiopia at a national scale, the level at which most policy decisions take place that affect the land husbandry and where environmental action plans are coordinated.

Degradation of land and water resources in Ethiopia has been accelerated due to a number of factors. It is crucial to address the problem and

the pertinent technical and political solutions should be sought. Three examples how politics is related to degradation in the past:

- One of the root causes of Ethiopia's poverty and deepening degradation is associated to the Derg regime and associated land and land tenure policy. The resilience and capacity of rural Ethiopia to cope with climate variability impact has been eroded immediately after nationalization of land. Rural Ethiopia used to have a buffer of grain accumulation on the hands of land lords and well to do farmers in traditional silos and storage mechanisms, prior to the Derg regime. Small impact of climate variability used to be contained by using such reserves without external aid, until it came to the out proportioned disasters that have occurred in 1974 in Northern Ethiopia. Unsecured partitioning of land in to small parcels not only created degradation but also abolished the social buffer coping strategy
- Nationalization of land and redistribution to the poor farmers was correct and just solution. However, ownership and use right of the land were not secured and in many parts of Ethiopia and use rights used to change hands in short period of time. This is one of the major responsible factors to cause mining of natural resources such as forest and lack of protection of soil. Farmers, once allocated land (temporarily), they take out all the possible resources from the land and never interested to invest on foresting, soil protection, etc except when forced by mass movement, which did not work
- Recently, important decisions have been made in relation to the issue of land use

right and certification, which potentially reverse the ill factors of the above. These should however be accompanied by land use policy and strategy that can help reversing degradation and enable regeneration of highly degraded environment.

A very fundamental and important issue is therefore to strengthen the use right and belongingness of farmers to their land and land resources so that they can invest on measures that help reversing degradation.

### 2.7 Lack of Finance and Capacity for Investment in Irrigation and Globalization

No doubt that, irrigation and investment in water infrastructure has transformed the socio-economy of many countries through increasing productivity, mechanization and modernization of agriculture, enhancing agro industries, enabling green revolution, etc. The investment in 1970's was also dictated by high food price. Figure 8, obtained from

Comprehensive Assessment (Molden, 2007), show such relationship of investment and food price.

Africa, has missed the past opportunity, due to low level of investment during the 1970's and investment was curtailed by making various reasons including low food price as pre text, and many pessimist argue it is not possible to repeat green revolution in Africa.

For low food price and competitiveness of poor countries and their farmers, there is no level playing field. OECD countries are giving their farmers some US\$380 BN annually – that is probably higher than the sum of the annual budget of SSA? The average EU farmer receives 35% of his/her income from government subsidies; a Swiss farmer gets 69%! Rijsberman, F (2006). Still under these conditions, Brazilian farmers or farmers from merging economies are succeeding, and why not countries like Ethiopia.

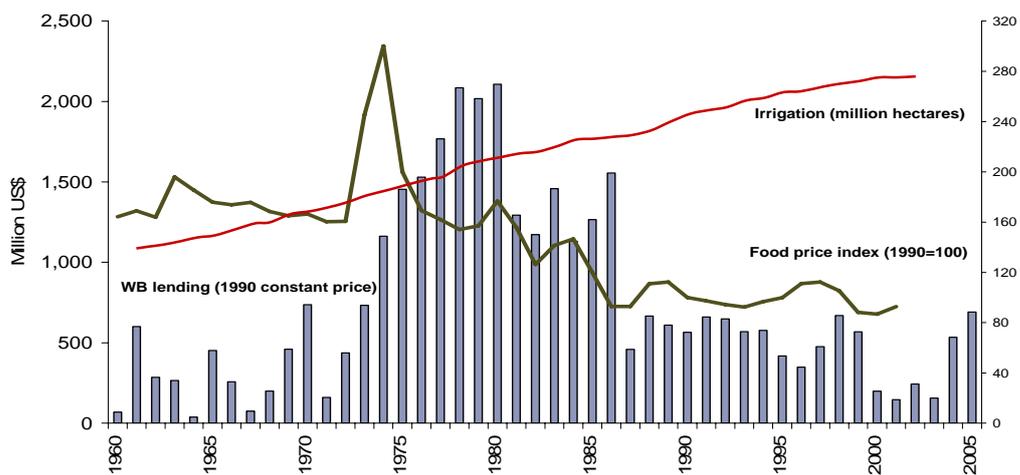


Figure 8: Food price and irrigation investment

Globalization continues over the long run, providing new opportunities for commercial and high-value agriculture but presenting new challenges for rural

development. Unless we act now, tomorrow is too late

Ethiopia indeed had problems of financing even if it has chosen to

invest in water, particularly irrigation. However, it is highly paramount to give this sector a priority, as started in the recent years. It is possible to lower investment cost by developing strategy for investment, such as focusing on multi purpose systems, target irrigation investment to high value crops, ascertain involvement of entrepreneurs in forward and back ward linkage, involve also foreign investors, etc

Ethiopia is essentially in a difficult position due to its Trans boundary nature of water resources. While working to enhance cooperation, bilateral relation and unilateral measures, we have to invest on tributary, non-trans boundary Rivers and less problematic rivers and at the same time seek long term and

permanent solution to the trans boundary problems. The past has shown that Ethiopia was not helped earnestly to develop its share of resources, and often bilateral supports fade away as dictated by the political interest in the Middle East.

### 3. Water Resources and Economic Linkage

Ethiopia has 12 river basins from which 8 are basins with significant quantities of flow. One of the basins is a Lake Basin having numerous lakes fed by a number of rivers and streams. The remaining 3 are dry basins receiving deficit rainfall that can not produce river and significant runoff overcoming evaporation. The basin map is shown on Figure 9

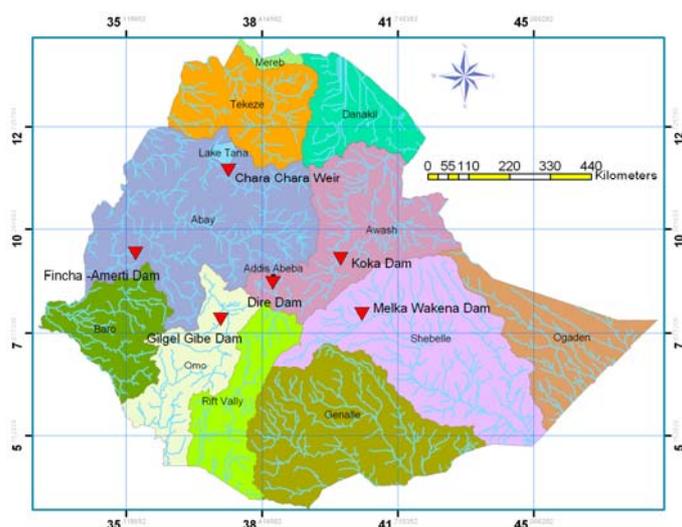


Figure 9: Map showing the 11 basins of Ethiopian rivers

#### 3.1 Water Resource Endowment: Is Ethiopia Really a Water Endowed Country?

Considering the above, Ethiopia is considered as the water tower of Eastern Africa. This is factually true when considering half of the country, particularly the western and South Western part of the country. The endowment can be used for productive purpose that can transform the countries socio-economy. However, as long as this resource is not available

for productive and economic purpose, physical availability during particular seasons of the year does not show economic availability and the country is considered as economically water scarce. The Eastern and North Eastern part of the country is having a double challenge of having both physical and economic scarcity. Figure 10 showing the rainfall distribution which reflects

the water scarcity and endowment in the various parts of the country.

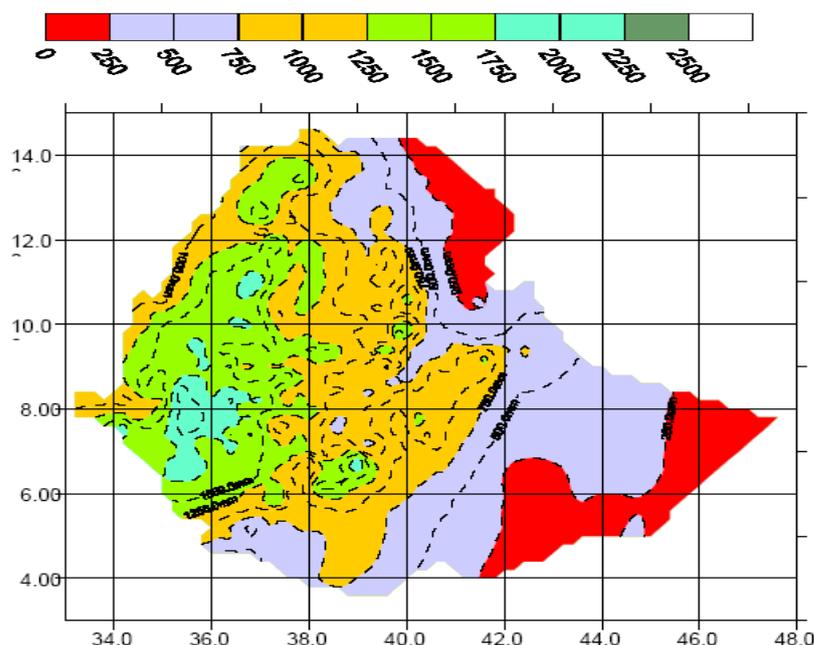


Figure 10: rainfall distribution in various parts of Ethiopia

Even the physical water availability is dwindling due to rapidly growing population. Figure 11 shows the per

capita averaged past and future physical water availability in Ethiopia.

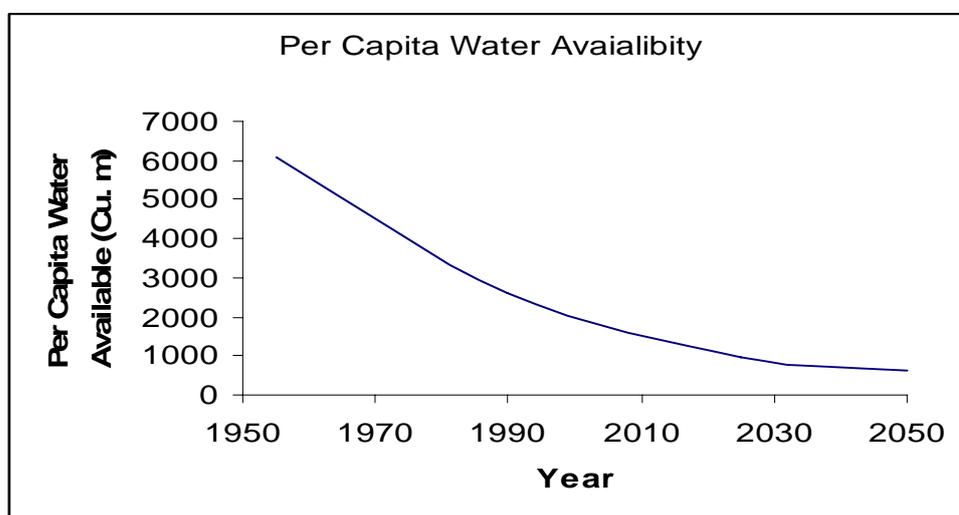


Figure 11: Per capita physical (not economical) water availability of Ethiopia

‘Water Poverty Index, attempts to reflect the physical availability of water (the degree to which humans are served by that water) and the maintenance of ecological integrity. The index clusters components in five dimensions: access to water; water

quantity, quality and variability; water uses for domestic, food and productive purposes; capacity for water management; and environmental aspects. By these measures, Ethiopia is water poor and heavily constrained by economic water scarcity

### 3.2 The Water Resources Infrastructure Need

This water resource from the excess runoff basins could, in principle, provide supplementary irrigation to overcome the effects of rainfall variability and overcome drought during the major and secondary rain seasons, as well as full irrigation during the dry season to intensify production and maximize the return on available land and water resources.

There are many challenges that must be confronted before water resources can be better utilized and productivity in agriculture is enhanced. Some of the most relevant ones with respect to agricultural water and availability of water are to overcome rainfall variability, dry spells and drought; increase availability of per capita storage for productive and consumptive purposes and even out the availability of water in space and time; overcome soil degradation and overcome water holding capacity and productivity problems.

Figure 12 (Awulachew, 2001) shows the phenomenon of temporal water resources distribution of major rivers in Ethiopia. The figure particularly shows that the scope of Ethiopian water resources to bring meaningful development without reliable water control infrastructure is minimal. The hydrograph distribution of all rivers show that there is considerable variation of runoff in a year, and considerable flow occurs in the period of Mid June to Mid October, where in most case no irrigation is needed except in erratic rainfall areas in the form of supplemental irrigation. Hence, we have to be convinced without confusion that, Ethiopia needs significant water storage to make leap frog in development. This issue becomes clear if one compares the per capita storage availability in developed, middle income and poor countries. The precipitate water storage in  $m^3$  in North America is over 6,000 , about 3,200 in Brazil, 1,300 in Thailand and 43 in Ethiopia (without considering the ones under current construction)

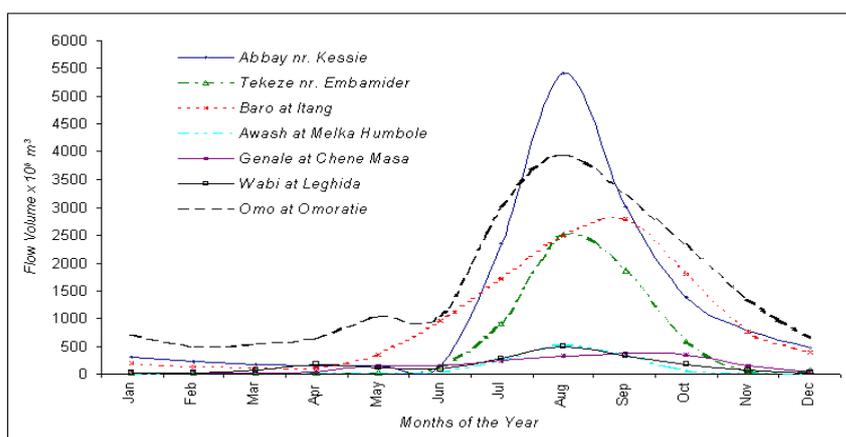


Figure 12: Temporal Water Distribution of Ethiopia

What should be new now is that the emphasis on ‘investments in water.’ Although it will become clear quickly that there is no such thing as investing in ‘water only’, articulating it this way does help to focus upon the issue. Physical and economic scarcity of

water is very common, and growing, problem in Ethiopia. Although it is not a magical single-factor solution, investments in water combined with complementary policies (for example, to encourage private enterprise) and infrastructure (for example, roads and communications) can bring the rural

and pre-urban poor a significant improvement in household food security, poverty relief and economic growth. The impact of investments in water will also be far greater, if accompanied by investments in other sectors, (such as roads, communications and health and by appropriate policies effectively implemented) and vice versa.

The bottom line, as shown in the following Figure obtained from the World Bank, the rate of return of investment on infrastructure is very high for countries in Type 1 level of

development, which is reflecting the actual current situation of Ethiopia. As also discussed in the WB CWRAS for Ethiopia, the hydraulic infrastructure investment should be a priority. Added to that Ethiopia's peculiar advantage of integrating various developments that combines consumptive (irrigation, domestic, industrial, urban water supply) and non consumptive (hydropower, flood protection, environmental services) water resources developments makes the rate of return very high.

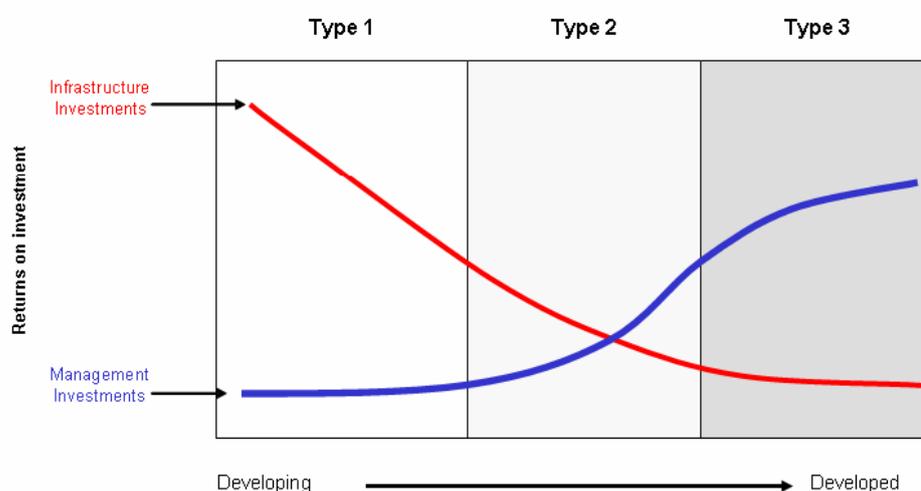


Figure 13: Schematic representation of rate of return of investments vs stage of development of water infrastructure (Sited in WB 2006)

Often, discussion of hydraulic infrastructures for water control and management confused with building dam only. The infrastructure or measures for agricultural water management for example can include dams, diversions, pumping stations, ground water wells, conveyance systems such as canals and pipes, shallow well development, flood harvesting, rain water harvesting, in situ moisture maximization, appropriate field water application, etc. The choice depends on the type of water resources available, the size and extent of development anticipated and

the available human, technological and financial capacities. Important is to have open attitude and approach towards all and possible combination combined with innovations.

In conclusion, Ethiopia's challenges are overwhelming and require innovations and key interventions to bring sustainable socio-economic development. Due to neglect in the past and lack of sufficient investment and resources development, the inhabitants of country is subjected to deep poverty, is in state of low resilience and coping strategies and having vulnerable economy. It is

important to think differently how to manage its resources effectively to overcome these situations. In the recent past the country has enjoyed growth. This must be made sustainable through key and strategic investment, among which water is an important entry point.

#### **4. Water-related innovations for agriculture**

##### **4.1 Lessons Learnt**

Despite, great emerging pace and encouraging development now, Ethiopia has not utilized its water resources effectively to transform agriculture and was subjected to all the calamities and key challenges by effects of rainfall and climate, as discussed earlier.

If water plays such a key role in Ethiopia's challenges, then why has it not been addressed already? Key issue is investment. Some people argue on this and generally on water resources development projects in Africa, particularly irrigation projects, have a reputation for being several times more expensive than Asian projects and for not delivering results. Books can be written on this to explain what went well, what went wrong and how could it be made working. Have we learned from the past and do we know where to invest in the future in Ethiopia? Can we put in place innovative policies and strategies? Is there a task for research, for science and technology, to develop such solutions?

Rijesberman, F (2006) discusses similar questions on SSA. For answering such challenges, Jeffrey Sachs's proposal is clear: we have the answers and the key is increased investments. Others, such as Lomborg, question whether there are good investment opportunities where the benefits to society clearly outweigh the investment costs.

For water, however, both camps came to the same conclusion: (1) for water supply and sanitation we have excellent investment opportunities; and (2) for increasing water productivity in agriculture, developing innovative solutions including using research is a good investment opportunity.

This has been also an emerging clarity from many people and decision makers in Ethiopia. World Bank responds that water resources development and management is a core issue for Ethiopia's development.

Therefore, can water play a key role in Ethiopia's transformation? Certainly, yes! It has been instrumental in Asia. Water use for human purposes, primarily for irrigated agriculture, increased six-fold in the 20th century. This has transformed agriculture, particularly in Asia and enabled miraculous economic growth, in the form of green revolution for example. The most important water-related innovations associated with this transformation in the 20th century were (Rijesberman, F 2006):

1. Large to very large dams, of which there are now over 45000 in the world, the majority constructed between 1960 and 1990 particularly in the US, Australia, China and India.
2. Small, cheap diesel and electric pumps which revolutionized irrigated agriculture in Asia, particularly in India and China, where over half of all irrigation is now from groundwater through an estimated 20 million pumps in India alone.
3. Pressure irrigation, i.e. forms of sprinkler and more recently drip irrigation, that have transformed irrigation in Israel, North Africa, Europe, and the Americas.

Innovations that have been much talked about, but that have had much less impact are the most heavily

promoted institutional and policy innovations, i.e. irrigation management transfer or participatory irrigation management and water pricing. Of course, they have to be put in place with correct institutional arrangements, with necessary effectiveness and needed efficiency. We are addressing these issues separately, and their importance should not mask the priority areas need, investment in the above 3.

A comprehensive recent study by International Water Management Institute, World Bank, African Development Bank, FAO and IFAD shows that, surprisingly, irrigation projects in Africa are not very much more expensive than in Asia. Small projects are more expensive than large projects, however, and there have been many more small projects in Africa than in Asia. Based on similar other studies key conclusions are:

- Farmers *are* the private sector.
- Large has a place: Large dams *can* be good and small dams *can* be bad.
- *Farmer participation* in irrigation O&M makes for better projects.
- Success is influenced by *other sectors*: fertilizer, roads, markets, output prices.
- *High-value crops* (vegetables, primarily) outperform staple foods by a considerable factor.
- Have *multiple-use* projects: domestic *and* productive use (crops, fish, livestock, trees and environmental services)

#### 4.2 Suggestions for Ethiopia Situation

Understanding the above, the current conditions and past experience in Ethiopia, we propose the following are the most important innovations and approaches towards improving water

management for agriculture that could lead to transformation of Ethiopian agricultural centered socio-economy growth:

1. Growth pole/center concept could be applied as a major socio-economic growth approach in selected areas of the country with precisely defined objective and as a National (Federal) undertaking. This yields various benefits among which resettlement and irrigation are prominent ones. It is absolutely essential to resettle people from heavily populated, extremely degraded high land to fertile areas. This, unlike in the past should be fully combined with irrigation and agro industrial development in major river valleys of Ethiopia. Consider educated, multi-disciplinary and organized farmers. Look in to primary outward markets, and how the sparsely populated, fertile, water reach boarder areas of Ethiopia, can be tapped in to nucleuses(growth poles/centers) of socio-economic development and export opportunities;
2. Improve water control, use and management: This could be from small dams up to large dams that could be used for single to multi purpose development. Investment becomes attractive and rate of return becomes high if we invest on multi purpose systems. Large scale irrigation can be combined with large scale hydropower and flood protection. This is proven, we do not need outside evidence for this and the small Koka and Fincha reservoirs are adequate examples. Opponents of such ideas may argue that large scale systems and dams are detrimental to environment, not sustainable, not pro poor, etc. Such group of people may bring out evidences of

some failed schemes. On the other hand, Ethiopia has proven record that such systems are working efficiently, are beneficial to the poor, beneficial to the environment and beneficial to the income of the state<sup>1</sup>. In fact, obsession and waste of time by such kind of discussions painfully delay accelerated growth. Up scaling this kind of systems, needs new way of thinking and innovation. The key to this is taking river corridors as entry point for new settlement strategy and growth pole, which is discussed separately;

3. The choices and types of interventions that need to be made in various zones could be variable. PASDEP identified water based agro-ecologies (adequate rainfall, moisture stress, pastoralist areas). As a case in point among these three systems, in addition to the discussion made in PASDEP

---

<sup>1</sup> The example of Koka dam and reservoir can illustrate this. The koka dam, built in 1950s, enabled generation of hydropower at the reservoir, enabled improved management of flood downstream (although not fully), helped to augment the low flow of upper and middle Awash, hence over 20,000ha of irrigation development, enabled green valley corridor, etc. If we just take the Wonji irrigation scheme, it is having about 6000ha state owned and about 1,500ha out growers (the latter, supplying about 25% cane requirement of the factory). This system and the integrated sugar industry employ about 5,000 permanent and over 7,000 casual workers plus over 1,200 out growers. If, however, the 6,000ha land is distributed to the same labor force as traditional subsistence farmers, it is highly possible that all would have lived under poverty. This system enabled a considerable benefit not only to have reliable income to the employees and the out growers but also to their dependents, when summed up together could be estimated to be over 40,000. The house holds under these systems, besides having good income that can not be obtained had it been under traditional farming, get better social facilities such as school, health service, electricity, water supply, etc. The system, since it is profitable, is also offering significant benefit to the economy of the nation

document, in pastoralist areas livestock are mostly the sole livelihood options. Livestock require a great deal of water. The quantity needed for drinking is not significant; however, if it is not available in reasonable distance and spatial distribution in these areas it can reduce the productivity of livestock quite substantially. The water required for feed production is quite significantly higher than the water for drinking.

- Make water availability and access at key spatial points
- Develop forage and animal feed resources using improved fodder technologies and irrigation
- Improve livestock productivity and livestock water productivity
- Ascertain that livestock are means of poverty alleviation and poverty creation, and not simply means of security, social status, etc,

Appropriate interventions based on these agro-ecologies and production systems can be identified depending on natural, technical, social, financial capacities supported by relevant research, study and intervention strategies. These require appropriate institutional and human resources capacity development;

4. There is strong rational to develop irrigation sector in Ethiopia and multiply the current effort. The reasons are:
  - Irrigation can increase productivity of land and labor, at least doubles
  - Without intensification of agriculture the country faces huge challenges to cope with population growth

- Irrigation reduces reliance on rainfall and mitigates the consequences of its variability
  - Irrigation can help mitigate agricultural expansion to marginal land and reduce degradation of natural resources
  - Ethiopia has significant untapped potential
  - Irrigated agriculture can contribute to the export market
  - Irrigation can create more job opportunities and foster dynamic economy and rural entrepreneurship through forward and backward linkages, etc
5. Invest also on large scale rainwater harvesting and associated technologies such as low-cost pressure irrigation, treadle pumps, etc. that will help improve water productivity of rain fed agriculture through better water management (and supplemental irrigation). Key to this is doing not make this a blanket recommendation. Identify areas where this makes meaning and return, such as low rainfall, moisture deficit and drought prone areas – and there maybe something to learn here from the Brazilian experience (e.g. re-introduction of the African grasses that have been developed into very successful fodder crops for the Brazilian cerrados);
  6. Large water infrastructure projects are capital intensive with long gestation periods. Based on experiences else where in the world (Egypt, Brazil, India, etc.,) these interventions are affected by government initiative and investment in some cases using PPP. Large scale regulation and control of water is made by public investment, deliberately, and can be made accessible to large scale investors or small holder irrigation sector entrepreneurs. Private sectors invited to utilize the water resources at secondary, or tertiary canal levels or on developed ground water wells, where by they are mainly expected to cover the O&M or in some case the water fee. For Ethiopia, it makes sense very much to follow such approach. The recently started Koga irrigation is a case in point. Many others should follow, with clear and conscious solution towards “cost recovery” issue when dealing with multilateral agencies.
  7. Enhance use of ground water combined with ground water recharge and watershed rehabilitation. Pumping of shallow and deep ground water in valley bottoms, and ground water potential areas can be an important entry point that needs to be given attention. Small diesel pumps for shallow wells at household or community based as well as deep tube wells can be used depending on the ground water resources availability and reliance. Means of water application could be drip, sprinkler or other forms of irrigation;
  8. Reform of public water management; even if water management is devolved to the lowest appropriate level, there remains a crucial role for government, particularly as basins close and water use needs to be (re-)allocated to higher value use(r)s at basin scale, but also to set water prices (or other incentives for wise use) and quality standards. There are issues to be resolved in upstream downstream interactions, inter-regional water allocation, etc.
  9. Enhance water resources management capacity and

institutions. Given Ethiopia's challenge on hydrology, low infrastructure, lack of dependable institutions, the need for such capacity is high. The capacity in the country is low and existing capacities are not also well utilized. Equally important is measures on how to reverse the brain drain. Existing capacity development efforts should continue. Investment in education in particular will be crucial to develop the capacity needed to plan, design and implement effective and appropriate water resource development and management interventions

10. Focused research in water is missing. Despite, attempts to come up with research priorities, justification of the needs, etc, research in the water sector is not established. Universities try to undertake ad-hoc research, which are not sufficient. MoWR established a research department, which has no developed capacity to undertake research or sponsor research. EIAR focuses on agriculture research that does not include water, and will not also in a position to address such issues in foreseeable future. It is timely and highly important to develop the water research system in Ethiopia, by having an independent institution which can also takes in to account and integrate the efforts of various universities and presence of global institution such as IWMI, which has wide experience in developing countries. Just two examples: Crop water requirement in various agro ecologies and for various crops is not known. Research can help to establish this which can help irrigation extensions to communicate to farm how much

water and when to apply to crop fields. Another example, Remote sensing, Geographic Information System (GIS) and hydrologic modeling research in Ethiopia can lead to seasonal drought forecasting, appropriate cultivation of crops as drought tolerant or high yielding, practical drought mitigation strategies and insurance and improved performance of reservoirs and irrigation systems. Marvelous results on water management and agricultural productivities in Egypt, Israel, Brazil, etc are dependent on adoptive and applied research pertinent to their own situation. Prosperity and breakthroughs for development of rich nations of the world is obtained through research. Ethiopia needs applied research which can put knowledge in to use through adoptions and adaptation

11. Multiple use systems that produce high water productivity by integration of domestic use with productive use for crops, livestock, fisheries, forestry and ecosystem services (as also mentioned under 1);
12. Public-private partnerships with government providing a favorable policy environment and access to markets, and the private sector providing the investments (as in Brazil, or Kenya). Parallel to discussion under point 4, above, there areas where the private sector can be attracted to invest. Ethiopia is now providing this opportunity, yet at smaller scale for example in flower industry. This favorable policies can extending to horticulture, and other agricultural product;

13. Clean water supply to rural and urban area is a key to productivity: Most of the diseases in Ethiopia is occurring as a result of water borne diseases, and in majority of child and infant mortality is associated due to lack of clean water supply and sanitation. Implementing the existing policy that makes water supply a priority should be effected. The progress in this highly encouraging. However, O&M issues are crucial, while investing in new systems. The target set in the PASDEP to bring down the malfunctioning system to 10% by 2010, from the current 30% is useful measure. However, it requires significant actions in terms of capacity, facilities and institutional investment; helps lowering investment cost. Parallel to this cascading systems are also effective way of harnessing this potential and lowering the investment cost (examples of Gilgel Ghibe, Mosel valley in Europe can be adopted wherever possible). Ethiopia can export this energy say to Sudan, Kenya, Djibouti and even North Africa and Europe to generate revenue, which can even outweigh the cost of fuel oil need. Hydropower is the one of the cleanest form of energy and can not be contested for environmental impact, except for the opinions of anti-dams. The water productivity of hydropower for energy is much higher than that of bio-fuels;
14. Hydropower is the white gold of Ethiopia that should be realized. Ethiopia's over 30,000MW potential of economically feasible renewable hydropower energy is an asset that needs to be exploited. No time in Ethiopia's history that this resource is under development than today. The target set to have 2,800MW generation by 2010 from current 791 MW is well underway. This should be further up scaled and continue with confidence for a number of reasons. If current growth continues for few years to come, Ethiopia's future energy consumption itself becomes very high. The benefit of water can feed one another where by the power generated at head dam can be used for pumping of water downstream or from deep wells to irrigate, to be utilized for power supply in manufacturing, agro industry, agro processing, etc. As discussed earlier, hydropower system combined with other consumptive sector development
15. Improve energy access: Rural Ethiopia is currently under energy crises situation. The need for fire wood combined with expansion of agricultural land due to population growth, uncontrolled usage of tree for construction, uncontrolled grazing are key elements for degradations. Limited and costly power supplies force reliance on biomass. Even urban poor do not use electricity for cooking, due to cost or lack of appropriate utensils. Ethiopia's current energy balance relies heavily on the use of fuel wood, crop residues, and dung. At the same time, removing these organic materials from the soil contributes significantly to land degradation and reduction of soil fertility. While accessing modern energy supply is a key issue, and the current plan of connecting 6000 villages with electricity, innovations are also needed how Ethiopia's rural system access appropriate household facility and reasonable cost of electricity that secures the benefit to the poor leading to

higher than using traditional energy;

16. Reverse degradation of Ethiopia: management of our watersheds is crucial for water resources, livelihoods, and the environment. However, we should not expect miracles from just watershed managements without entering in to the phase of investment which enables control, use and management of water that combines soil, forest and other natural resources. Improvements in watershed management, land use planning, and forest management will be crucial in managing water resources and river ecosystems more broadly. Improved watershed management can slow watershed erosion, moderate the hydrological cycle, regulate runoff and groundwater, improve infiltration, water retention and base flows, and reduce potential flood damage. An important lesson from experience in Ethiopia is the need to effectively include stakeholders in the planning, design, and management of watershed interventions. In addition to the above, a new innovation for Ethiopia's natural resources renewal and reversal of degradation are: resettlement combined with irrigation as discussed in the river corridor based growth pole, creating enclosures of highly degraded areas, provision of clearly defined land use plan (example stop cultivating crop say above 30% slope but use such landscape for high value tree crops, fodder production, agro forestry and indigenous trees), invest on interventions that can reverse degradation;

17. Incorporating the needs of livestock in to water planning and management could bring big benefits. Such integration, particularly in the pastoralist and poor livestock keepers help to get more from their animals, while using less water and more accessible to improve livestock productivity, reduce degradation of land and water resources

18. Ethiopia should look in to synergizing investments of various sectors such as roads, market linkage, and industry and water infrastructure. Investment in new valleys for example should be accompanied with this kind of synergies and look outward markets and development of necessary infrastructure towards such goals;

19. While undertaking necessary interventions in the highly vulnerable areas, Ethiopia should rethink on its focus. The past billions of dollars investment to enable survival of the worst affected areas due to climate variability have not transformed Ethiopia. The country should be able to identify growth pole zones such as river corridors and valleys to relocate its people, investment and focus.

## **5. Policy Actions Needed**

Despite remarkable efforts, record growth in the last few years, Ethiopia's agricultural system is not yet significantly benefiting from the technologies and innovations of water management and irrigation that could improve productivity and significantly reduce the vulnerability of the agricultural system to climatic variability. The majority of the poorest are rural dwellers who have limited

access to agricultural technology, limited possibility to diversify agricultural production, and cope with underdeveloped rural infrastructure, and weak access (sometimes lack of access) to agricultural markets. These issues combined with increasing degradation of the natural resource base, especially in highlands, aggravate the incidence of poverty and food insecurity in rural areas. Improved water management for agricultural could help not only coping with variability and reduce vulnerability but also, it is an important entry point to break the vicious cycle of poverty by improving productivity. Despite significant efforts of government and other stakeholders to improve agricultural water management and enhance irrigation a number of constraints related to policy, institutions, strategy, technology, capacity, infrastructure and market exist. Addressing these constraints is vital to achieve sustainable growth and accelerated development of the sector in Ethiopia. We have put the following necessary measures in relation to policy that can contribute to the accelerated socio-economic growth and in line with mainly taking water as entry point. These measures however need further enrichment through study, research and dialogue

***Policy action 1: Add dynamism, synergies and completeness to the exiting policies, strategies and sector development plans***

Having the existing water policy is good, and was expected for many years in the past. However, it should be very well communicated to the society. It should have adequate implementing capacities and implementation strategy, with well defined measures in terms of human resources, institutions, etc. It should be dynamic enough to include versatile overall theories one such proposed approach being Growth pole/corridor, which should have water

as one of its solid pillars or input. Water should be seen in this context as an economic propelling factor that has the capacity to create linkages between primarily agricultural producing systems that would give rise to non agricultural production.. The policy should have adequate M&E in place. Irrigation sector strategy and sector development plan for example need to be revised based on new information and economic development, the main agenda being installing the efficient and effective PPP. The small scale irrigation sector strategy should be clearly put in place. What can be done at federal, regional, river basin, watershed, and household levels should be clearly defined. Mandate and responsibilities should be complementary and synergetic not competing. Government's decisive role as a catalyst for wealth creation, in the irrigation sector, has to be enhanced through PPP.

***Policy action 2: Change the way we think about water and agriculture.***

Thinking differently about water is essential for achieving our multiple goals of ensuring food security, reducing poverty, transforming socio-economy of Ethiopia rapidly, and benefiting the environment. Instead of reliance on rainfall only, think of rainfall is the source of water that should be captured at all phases for beneficial purposes. View rain as the ultimate source of water that can be managed. Invest on water control infrastructure. Unless we invest in these systems in Ethiopia, growth of agriculture and socio-economy remains marginal. Focus on rain, rivers and groundwater. Instead of blueprint designs, craft institutions while recognizing the politically contentious nature of the reform process. And instead of isolating agriculture including irrigation as a production system, view it as an integrated multiple-use system.

***Policy action 3: Fight poverty by improving access to agricultural water and its use: Develop water sector entrepreneurship.***

Target livelihood gains of stake holding farmers (irrigation entrepreneurs) by securing water access through water rights and investments in water storage and delivery infrastructure where needed, improving value obtained by water use through improved and affordable technologies, and investing in infrastructures such as roads and markets. Multiple-use systems—operated for domestic use, crop production, aquaculture, agro-forestry, forestry and livestock—can improve water productivity and reduce poverty. Empowering entrepreneurs to use water better, and targeting the right groups by ensuring the right to secure access, improving governance of water resources, supporting the diversification of livelihoods, targeting industrious entrepreneurs—in irrigated areas—offers the best chance for reducing poverty quickly. This should also open space new thinking for entrepreneurship development, investment, etc

***Policy action 4: Manage agriculture to enhance environment and ecosystem services.***

Good agricultural practice can enhance other environmental ecosystem services. In agro ecosystems there is scope to promote services beyond the production of food, fiber, and animal protein. Agricultural production does not have to be at the expense of other services that water provides in rivers and wetlands. But because of increased water and land use, and intensification, some ecosystem change is unavoidable, and some times difficult choices are necessary. The issues in Ethiopia are that our environment and ecosystem are devastated due to poor agricultural practices that have never

addressed the water issues seriously and appropriately. Absence of proper water management and lack of productivity are responsible to have almost no conservation area and degradation in most part of the country

***Policy action 5: Increase the productivity of water***

Learning from past experience and experience of other countries, we should also focus on getting more yield and value from less water. Such approaches have the benefit of meeting reduction of future demand for water, limiting environmental degradation and easing competition for water. Similar to multiple use system, multi purpose development provide such opportunity. Improving efficiency and performance of existing schemes, including understanding the cause and revitalizing the failed systems will help improving the productivity

***Policy action 6: Upgrade rain fed systems***

Rain fed agriculture is upgraded by improving soil moisture conservation (note the importance in crop fields) and, where feasible, providing supplemental irrigation. Unlike in the past of focusing on just seed and fertilizer, water management in the rain fed system should be given adequate attention. This should not also be confused with full irrigation systems. These techniques hold underexploited potential for quickly lifting the greatest number of people out of poverty and for increasing water productivity. Investment only in one, namely water or soil fertility (fertilizer) or seed may only increase productivity by 50% percent. If the three are combined together productivity can increase to 300%. Mixed crop and livestock systems hold good potential, with the increased demand for livestock products and the scope for improving the productivity of these systems.

***Policy action 7: Reform the reform process—targeting state institutions.***

Following a realistic process to suit local needs, a major policy shift is required for water management investments important to irrigated, rain fed agriculture and water management. A wider policy and investment arena needs to be opened by breaking down the divides between rain fed and irrigated agriculture, small and large, federal and regional. It is important to link sub-sectoral investments to synergize by talking and planning together. Reform cannot follow a blueprint. It takes time. It requires discussion, negotiation and coalition building. Civil society and the private sector are important actors. But the state is often the critical driver, though state water institutions are often the most in need of reform. Establish the Ethiopian Water Council/commission under the Ministry of Water Resources that would

- consist of Government, Line Ministries, NGO, Civil Society, Regional States, etc
- forges water as central element in the evolvement of the Growth pole and other growth interventions
- Asserts that all water related projects/programmes/interventions are stream lined synergized and integrated within river basin planning frame work.
- Advises the government on trans-regional and trans-boundary river systems utilization, management, etc.

***Policy action 8: Deal with tradeoffs and make difficult choices.***

Because people do not adapt quickly to changing environments, bold steps are needed to engage with stakeholders. Informed multi stakeholder awareness creation, discussions, negotiations are essential to make decisions about the development, use and allocation of water. Reconciling competing

demands on water requires transparent sharing of information and choosing optimum strategy that would ultimately benefit all.

***Policy action 9: Define growth corridors***

It is possible to define growth corridors, taking river valleys, which can adequately feed Ethiopia and enhance national income. Urgent definition of these corridors is essential

***Policy action 10: Resettle people from degraded area to high potential areas with irrigation potential***

Many countries in the world can be cited as example. Reduce resettlement from degraded areas to virgin area with out irrigation is inferior compared to resettlement to irrigation potential areas. The environmental degradation implication is also quite significant and at times can be disastrous. It is better to make such resettlement with well designed strategy that includes irrigation and agro industrial development

***Policy action 11: Settle groups of educated farmers***

New development areas and corridors should be inhibited by combination of educated farmers of skill mixes, with adequate financial loans, access to land, infrastructure, facility, linkage to investors, etc.

***Policy action 12: Develop research and capacity building of water in Ethiopia***

No one in Ethiopia current claims in undertaking coherent and effective water and agricultural water management research, and there is huge gap in terms of undertaking, focus, capacity, ownership and institutionalization. There is strong usefulness of research to enhance development. The country needs water research pertinent to policy, institutions, technologies, agricultural

and water productivity, Tran's boundary, climate variability, etc issues. The current efforts are not supported with the necessary instruments such as budget, facility and manpower

***Policy Action 13: Livestock and pastoralist***

Policies leading to strategic sourcing of animal feeds, strategic provision of drinking water, enhancing animal productivity and reducing herd sizes are important interventions needed. It is important to manage livestock in a way that it can provide more benefit, reduce land, water and ecosystem degradation.

***Policy Action 14: Manage human resource and capacity***

Some of key public institutions are suffering due to not only brain drain but also internal migration. It is important to ascertain that public institutions do not lose capacity, drained during reform processes. Ethiopian water expertise in Diaspora community is probably higher than what exists in Ethiopia. Policy and strategy to harness this capacity should be seen as part and parcel of managing the internal capacity.

***Policy Action 15: Commit and raise necessary financial resources***

It is important to allocate sufficient public funding, clearly and deliberately earmarked for these key interventions. It is important to establish and develop the water resources fund, considering the entire citizen at home and abroad.

***Policy Action 16: Enhance and encourage key institutions and CSO***

Integrate water in agricultural research by building relevant capacity. Developing an independent water research institute is long overdue, and such institute is strategic for Ethiopia. Accepting water advisory council at

various levels is one means of tapping in to the potential of the HR capacity of the country. Establishing/strengthening Ethiopian Water Resources and related associations can contribute to the development and enhance the engagement, thinking and involvement of professionals.

In conclusion, the above key lessons and policy interventions and actions are proposed based on the prevailing situation, key problems and challenges identified in the context of previous sections. These are suggestions that require further discussions, enrichment, actions and not blue prints. They can serve as important discussion and way forward issues that can involve key professionals, policy makers, and citizens of Ethiopia. We encourage that these be brought to the wider framework of the think tank group.

**References**

- Awulachew, Seleshi Bekele, (2005): Experiences and Opportunities for Promoting Small-Scale/Micro Irrigation and Rainwater Harvesting for Food Security in Ethiopia, Working Paper 98.
- Awulachew, Seleshi Bekele (2001). Investigation of Water Resources Aimed at Multipurpose Development. Ph.D. Thesis.
- MOFED: PASDEP (2006). Ethiopia: Building on Progress. A Plan for Accelerated and Sustained Development to End Poverty (PASDEP), Volume I: Main Text.
- Molden, David (2007). Comprehensive Assessment of Water Management in Agriculture, 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan, and Colombo: International Water Management Institute.

- Johan Rocksstrom, Matts Lannerstand, and Malin Falkenmark (2007). Assessing the water challenge of a new green revolution in developing countries, PNAS, April 2007. [www.pnas.org#otherarticles](http://www.pnas.org#otherarticles)
- The World Bank (WB) (2006) Managing Water Resources to Maximize Sustainable Growth. Ethiopia Country Water Resources Assistance Strategy document.
- World Bank. 2003. *Source book for agricultural investments*. Draft, December 2003
- Hurni H. 1993. Land degradation, famines and resource scenarios in Ethiopia. In *World Soil Erosion and Conservation*, Pimentel D (ed.). Cambridge University Press: Cambridge; 27–62.
- Rijsberman, F (2006). What Can Water Science and Technology do for Africa, IWMI.