

Best bets technologies for improving agricultural water management and system intensification in Ethiopia

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Abstract

Significant part of Ethiopia and its agricultural production is affected by prolonged dry spells, recurrent drought, land degradation and consequential low productivity, extreme poverty and highly vulnerable. This paper first deals with the various technologies used with respect to agricultural water management, and provide description of suits of technologies that are common for agricultural water management (AWM) in Ethiopia. Secondly, it evaluates the poverty impact of the various technologies based on extensive data that are collected from 1,500 households that are currently practicing these technologies in four major regions of Ethiopia. The final part of the paper deals with the integrated interventions for improving crop water productivity through combination of technologies and system intensification, using the case study. In Ethiopia, both in-situ water management and ex-situ water management technologies are used. Among the in-situ water management soil and water conservation technologies use of terracing, stone bunds, trash lines etc are common. However, evaluation of their use on crop production and productivity impact is difficult and not well established in Ethiopia. Among the ex-situ including rain water harvesting technologies ponds, river diversion, micro dams, wells and pump irrigation are most common. Based on poverty analysis, the incidence, depth and severity of poverty is less among users of technology compared to non-users and the results are statistically robust. Accordingly, users AWM technology are 22 percent less poor compared to non-users or pure rain fed systems without AWM. The high impact technologies are found to be deep well, diversion and micro dams leading to 50%, 32%, and 25% poverty reductions respectively. The difference is mostly attributed to the scale effect and reliability of systems. AWM was best exploited when it was accompanied by improved soil fertility management interventions. Yield gains of upto 2000% were obtained when Zai pits (i.e. small water harvesting trenches) were augmented by application of chemical and organic fertilizers. Integrating legume cover crops increased yield of succeeding crop significantly while improving soil fertility and water holding capacity. The effect of fertilizer application was highly pronounced when legumes were integrated into the cropping system. Growing varietal mixtures of different height and maturity period increased crop yield by up to 60% through compensation effects and better use of water and soil nutrients over time and space. Therefore, in order to improve agricultural productivity, effectively reduce poverty it is essential that the rainfall and agricultural water is managed, accompanied by soil fertility management and agronomic practices.

1. Introduction

1.1 General

With its human population estimated at 77 million in 2007 which increases annually at about 2.8 per cent, adding nearly 2 million each year, Ethiopia is the second most populous country in sub-Saharan Africa next to Nigeria. The main mainstay of the country's economy is agriculture which contributes about 45% and 85% to the GDP and the national export earnings, respectively. Largely dependent on the highly variable rainfall, coupled with the rampant land degradation agricultural productivity continues to decline or stagnate to perpetuate poverty, food and 'human needs insecurity' and increased vulnerability to the recurrent drought. Recurrent drought is one of the major threats to food security and sustainable use and conservation of natural resources in Ethiopia. The rural poor in Ethiopia are often trapped in this vicious cycle between poor access to resources (poverty), land degradation and recurrent drought. Inefficient water management in the rain-fed agriculture coupled with accelerated land degradation also played an important role in aggravating the recurrent food insecurity in the country. In the face of current soaring food prices in the international markets, importing agricultural products through purchase or aid is becoming more challenging than ever before, calling for substantial increase in agricultural productivity. Thus, a widespread implementation of improved land and water management systems that ensures sustainable development based on the relative advantage of the different agro-ecological and geographic settings of the country is a matter of urgency in order to ensure food security both at national and household levels and to fuel the economic development of the country.

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1.2 Crop Production in Ethiopia

According to CSA (2006), the major crops grown in the country are cereals (bread wheat (*Triticum aestivum* L, Durum wheat (*T. durum* Desf), tef (*Eragrostis tef*), maize (*Zea mays*) and barley (*Hordeum vulgare*)) and various other crops such as pulses, oil seeds, root crops, fruit crops, sesame (*Sesamum indicum*), cotton (*Gossypium sp.*), sugar cane (*Saccharum*), chat (*Catha edulis*) and coffee. Cereals, pulses and oil seeds cover about 95% of the total area (Source....). Cereals alone cover 75 % of the total area out of which tef covers the largest area followed by maize, sorghum, wheat and barley, respectively. However, in terms of production, maize contributes the largest grain yield followed by wheat, tef, sorghum and barley. These crops could be cultivated either under rain-fed or irrigated conditions, but currently they are largely cultivated as rain-fed crops. Coffee, cotton,

sesame and sugar cane which have high potential for export earning constitute small proportion of the total production.

About 20 % of the total arable land, exceeding 10 Million ha of the country has been put under cultivation. Irrigation coverage is estimated at about 6% of the countries 3.7 Million hectares. Although there are some large scale commercial irrigation farms producing mainly industrial or export crops, the semi-subsistent and traditional rain-fed farming together with the limited small scale traditional irrigation farms contribute the largest share in the total agricultural production.

1.3 Rainfed System

Rain-fed agriculture contributes the largest share in the total agricultural production in Ethiopia and this is expected to continue in the foreseeable future as indicated in the sustained increase in land area under rain-fed farming. According to CSA (2006), the size of agricultural land occupied by rain-fed agriculture during 2003/04 to 2005/06 increased from 9.5 M ha to 10.4 M ha, which shows an increase of 9.5 % while production was reported to have increased 12 to 15% every year. The higher rate of yield increase as compared to the increase in area coverage could be attributed to the increased use of improved inputs such as fertilizers and favorable weather conditions of the year 2005/06. The rain-fed system could not keep pace with the population growth under the prevailing management; there is a substantial room for improvement of its productivity though, partly due to climate related constraints and other limitations?. As a result, the country is entangled in abject poverty and persistently faced with chronic food deficit since early 1970's. Therefore, while the endeavor to significantly enhance the productivity of the rain-fed system through the use of improved technologies such as superior crop varieties and appropriate type and quantity of fertilizers, suitable water management technologies including irrigation and drainage deserve due consideration to accelerate the progress in the poverty reduction front.

1.4 Irrigated Systems

Irrigation is among the technological interventions believed necessary to achieve a major increase in agricultural productivity to meet the growing demand for agricultural products in Ethiopia. The major crops commonly grown under irrigation are sugar cane, cotton, sesame, fruits and vegetables. These crops are grown under small and traditional as well as medium to large scale irrigation schemes. While the major food crops are under the rain-fed system, irrigation has been seen as a means to provide employment opportunities and increase the livelihood of rural people by enabling them grow cash crops. However, the toiling mass of Ethiopian farmers is at best having access to small scale or traditional irrigation which is less costly, and often can be easily integrated into the rain-fed and livestock farming. Consequently, the contribution of irrigation to the economy is insignificant. According to Hagos *et al* (Forthcoming), irrigation contributed about 5.7 and 2.5 percent, respectively, of the agricultural and overall GDP during the 2005/06 cropping season. This is despite its higher relative efficiency, that smallholder managed irrigation systems generated an average income of about USD 323/ha compared to an average income of USD 147/ha obtained under rain-fed system Hagos *et al* (Forthcoming). Therefore, expanding the use of irrigation systems is believed to ensure increased income of the smallholders and thereby stimulates rural development. Also, its increased contribution to the agricultural and overall GDP will fuel the overall economic development efforts of the country.

1.5 Objective of the paper

The objectives of this paper is 1) review the various technologies used in Ethiopia in relation to agricultural water management and describe the suits of these technologies i.e. how they are combined with respect to rain or water control, conveyance and application 2) look in to the impact of these technologies with respect to poverty reduction and household income 3) Through a long term study on specific rain water management technology, evaluate the impact of the technology and its integration with other interventions with respect to water and crop productivity

2. Review of AWM technologies and their suites

2.1 Technologies widely practiced

The overall objective of this component is aimed at assessing suitability of AWMT and identification of promising technologies for scaling up. The method of collecting data and information included literature review from both local and international sources, key informants were identified at federal, regional and in some instances at zonal and woreda levels; interviews and discussions were held at all levels. In addition, a questionnaire was designed and distributed to relevant experts in various institutions (GO, NGO, UN agencies, private, etc) to capture diversified information on agricultural water management practices, ranking of technologies including the constraints that exist. Where conditions favor site observations were made and discussion with individual farmers were also held. In total 38 different types of AWM technologies for rainfall and water conservation/control are identified that are practiced in Ethiopia as micro catchment (eg. stone terraces, trash lines) and macro catchment (eg ponds, small dams, diversion) technologies. Based on the inventory, interviews and ranking the following table provide the most promising type of technologies in the four major regions of Ethiopia

Table 1: Major AWM Technologies Practiced in the Four Major Regions of Ethiopia

Rank	Tigray	Amhara	Oromia	SNNPR
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1.	River Diversion	River diversion	Wells	River diversion
2.	Micro dam	Micro dams	River diversion	Pump irrigation (from perennial river)
3.	Wells	Wells	Pond	Dams
4.	Ponds	Pond	Spate	Ponds
5.	Tankers		Terraces	Soil bund
6.			Dams	

3.2 Suits of Technologies

Very often, technologies of AWM are advocated in isolation of particular function. While this is applicable for most of the in situ technologies of soil and water conservation type of functions, for the ex-situ type of systems actually require more than one combination of technologies. This usually includes all or some of the technologies used for water control/storage, water lifting, conveyance and field application. The suits of technologies relates to how these technologies are combined and used. The factors that influence these combinations are many. Affordability, experience, availability, lack of awareness are some to mention. Technology suits mostly practiced in Ethiopia are shown in Annex. 12. However, one cannot deny the existence of other technology suits in use. Annex 12 also shows the location of these technologies where they are widely adopted and practiced in Ethiopia

In our analysis of suits of technologies, we have identified the following as the main ones:

3.2.1 Rainwater Harvesting Suits

Pond → bucket/watering can/pulley/siphon → flooding
 Pond → bucket/ pressure treadle pump → storage drum (with/without) → drip/sprinkler
 Pond → suction treadle pump/rope and washer pump → channel → flooding
 Hemi-spherical tank (mortar) → channel → flooding
 Dome shaped tank (concrete) → channel → flooding
 Spring → / motorized pump + storage) → channel → flooding
 Spate irrigation (gully plugging, stone bund and water spreading)
 Roof rain water harvesting → surface/underground tank → watering can
 Subsurface dam → hand/motorized pump → Flooding

3.2.2 Micro Irrigation Suits

Shallow well → bucket/hand/(motorized pump + drip) storage drum → drip
 Shallow well → treadle/motorized pump → (canal + furrow)/sprinkler
 Deep well → motorized pump → drip/sprinkler

3.2.3 Small Scale Irrigation Suits

Earth dam → Canal → furrow/flooding
 Diversion weir → Canal → furrow/flooding
 River → motorized pump → outlet chamber → canal → furrow/flooding

3. Poverty Impact of AWM technologies

3.1 Method and Data

The main focus of this paper was to explore whether access to selected AWMTs, such as deep and shallow wells, ponds, river diversions and small dams, has led to significant reduction in poverty, and if they did to identify which technologies have higher impacts. In measuring impact we followed different approaches: mean separation tests, propensity score matching and poverty analysis. The study used a unique dataset from a representative sample of 1517 households from 29 Peasant Associations (Kebeles) in four regions of Ethiopia.

The socio-economic survey data gathered from a total sample of 1517 households from 29 study sites (peasant associations) in 4 Regional states. The PAs were selected based on the presence of identified promising technologies. Then the households from each PA were selected based on the criterion of their access to AWM technologies vs. no access using non-proportional random sampling. Details of the sample households by type of technologies from the four regions are given below in table 2. This selection was based first on the identification of promising technologies through key informant interviews mentioned above. For details see Loulseged, et al. 2008. The data was collected for the 2006/2007 cropping season.

Table 2: Summary of sample households

Region	Agricultural water management technologies						
	Purely rainfed	Pond	Shallow wells	Deep wells	River diversion	Micro dams	others
Amhara	281	8	45	10	28	13	5
Oromia	219	12	23	68	68	1	2
SNNPR	217	68	55	0	14	25	0
Tigray	143	47	91	1	40	35	18

Total	860	657
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3.2 Poverty Analysis Results

In brief the analysis of poverty followed six steps. First, we have chosen household consumption expenditure as welfare measure and this was adjusted for the size and composition of the household. Second, the consumption poverty line is set at 1821.05 Birr (1USD=9.2 Birr), an inflation-adjusted poverty line of the baseline poverty line of ETB 1075 set in 1995/96 as measure of welfare corresponding to some minimum acceptable standard of living in Ethiopia (MOFED, 2006). We also used an inflation-adjusted poverty line of 1096.03 as absolute food poverty line based on the corresponding 1995/96 food poverty line. These lines were chosen to enable meaningful comparison of poverty levels in Ethiopia between various groups and over time (in reference to earlier studies). The poverty line acts as a threshold, with households falling below the poverty line considered poor and those above the poverty line considered non-poor. Third, after the poor has been identified, poverty indices such as head count, poverty gap and poverty gap squared were estimated. Fourth, we constructed poverty profiles showing how poverty varies over population subgroups (example users Vs non-users) or by other characteristics of the household (for example, level of education, age, asset holding, location, etc.). The poverty profiling is particularly important as what matters most to policymakers is not so much the precise location of the poverty line, but the implied poverty comparison across subgroups or across time. Furthermore, we undertook ordinal poverty comparisons using stochastic dominance tests to test the robustness of the poverty orderings. This is important because the estimation of the poverty line could be influenced by measurement error. Lastly, we explored the determinants of poverty using multivariate regression analysis. We analyzed the correlates of poverty against household and demographic factors, specific individual/household head characteristics, asset holdings including adoption of and use AWM technologies, village level factors, and policy related variables (access to services). By doing so, the marginal impact of access to AWM technologies on poverty was assessed while controlling for other possible covariates.

Our results show that there was significant reduction in poverty from use of AWMT. In fact, our calculations show that there is about 22% less poverty among users compared to non-users of AWMT. The magnitude of poverty reduction is technology specific. Accordingly, deep wells, river diversions and micro dams have led to 50, 32 and 25 percent reduction in poverty levels compared to the reference, i.e. rain fed system. This may imply that there is a need to promote more micro dams, deep wells and river diversions for higher impact on poverty. Use of modern water withdrawal technologies (treadle pumps and motorized pumps) were also found to have strong poverty reducing potential. Households using of motorized pumps were found to have led to more than 50 percent reduction in the incidence of poverty. Similarly, households using gravity irrigation were found to have significantly lower poverty levels compared to those using manual (using cans) applications because of scale benefits. This implies that promotion of modern water withdrawal and application technologies could enhance poverty reduction. But this will also have important impact on choice of technology, i.e. to focus on macro than micro-water harvesting technologies for effective poverty reduction. We found the poverty orderings between users and non-users are statistically robust. Furthermore, from the poverty analysis (severity indices), we have found that AWMT are not only effectively poverty-reducing but also equity-enhancing technologies. Equitable development is good for the poor and for better performance of the economy (Ravallion, 2005).

While poverty analysis techniques do not have in-built mechanisms of creating comparable groups, and hence, could lead to attribution bias¹, our results from the propensity score matching, however, indicated that the average treatment effect of using AWMT is significant and has led to an increase in income which amounts to average income of USD 82/ household.

While access to AWMT seems to unambiguously reduce poverty, our study also indicated that there are a host of factors that could enhance this impact. The most important determinants include asset holdings, educational attainment, underutilization of family labor and poor access to services and markets. To enhance the contribution of AWMT to poverty reduction, there is, hence, a need to: i) build assets; ii) human resource development; and iii) improve the functioning of labor markets and access to markets (input or output markets). These areas could provide entry points for policy interventions to complement improved access to AWMT in Ethiopia.

4. Interventions for increasing crop production

4.1 In situ water management interventions

One of the most appreciated techniques by farmers in Southern Ethiopia was the plant-pit system or "Zai", originated in Mali and was adopted and improved in northern Burkina Faso (Roose et al., 1999). There was a significant yield advantage difference from zai plots over traditional land management practices in Southern Ethiopia (Amede et al. 2008). For instance, Potato yield was significantly higher

¹ The baseline situation of users and non-users is not known, one could argue that the difference in estimated poverty levels may have to do with differences in initial conditions.

in Zai pits than those planted in flat fields. The yield advantage of the Zai was ranging from 5 xs to 20 xs depending on the landscape positions. The effect of different levels of fertilizers on tuber yield was pronounced mainly when accompanied by Zai pits. In addition to crop yield, soil moisture content of the Zai pits was significantly higher than in the flat planting; the difference was by about 10% higher. Water productivity has also tripled with Zai interventions, without any considerable change in nutrient status of the soils (Amede et al. 2008). It also suggests that higher soil water content in the Zai was due more to physical conservation of water by the pits than contributions made by the manure. A higher water budget was also reported from fields with organic fertilizer and conservation tillage compared to chemical fertilizers or conventional tillage (Yaduvanshi and Sharma 2008). Similarly, zai pits were also found to improve the water productivity of millets in the Sahel by a factor of 2 (Fatondji et al., 2007).

4.2 Integrated Nutrient Management

Over-mining of nutrients is an important factor contributing to decline in soil fertility in Ethiopian highlands. The system received external inputs very rarely with a fertilizer rate of less than 10 kg/ha (Quinones et al., 1997). The concept of integrated nutrient management through combination of organic and inorganic nutrient resources has been rarely practiced as the system is in shortage of organic biomass. This ensures both efficient and economic use of scarce nutrient resources. Various sources of nutrients and approaches have been tested in Ethiopia to improve soil fertility of farms and landscapes.

i) Improving soil organic matter

The major problem of Ethiopia soils is associated with low soil organic matter content, which commonly dictates nutrient availability & storage, underground biodiversity, soil water holding capacity and many other biological and chemical processes. On the other hand, building organic matter of soils in the short term requires a combination of interventions including improved organic residue management, deliberate crop rotations, improved soil biota and their biological processes and minimizing carbon loss through soil conservation.

One key intervention tested in Ethiopia was integration of legume cover crops (LCCs). Legume cover crops could produce up to 10 ton/ha dry biomass within four months (Amede and Kirkby, 2004), and are also fixing up to 120 kg N per season (Giller, 2002). High quality legumes tested in the Ethiopian highlands include tephrosia, mucuna, crotalaria, canavalia, and vetch (Amede & Kirkby, 2004). However, despite a significant after effect of LCCs on the preceding maize yield (up to 500% yield advantage over the local management) farmers were reluctant to adopt the legume technology because of trade-off effects for food, feed and soil fertility purposes (Amede, unpublished data, 2002). In an attempt to understand factors affecting integration of soil improving legumes in to the farming systems of southern Ethiopia, Amede & Kirkby (2004) identified the following socio-economic criteria of farmers as determinants of adoption namely, soil fertility status of farms and landscapes, farm size, land ownership, access to market and demand for livestock feed.

Another source of organic fertilizer is farm yard manure. There is an apparently strong competition for manure use between soil fertility and cooking fuel. Recent survey in the upper central highlands of Ethiopia showed that more than 80% of the manure is used as a source of fuel. Further more, the available manure is of low quality; N fertilizer equivalency values of less than 30%, sometimes with high initial quality that did not explain the quality of the manure at times of use (Murwira et al., 2002). The manure quality is also variable; wet season manure has a higher nutrient content than dry season manure, and pit manure has a better quality than piled manure. Besides, the quantity of manure produced per farm is small. Sandford (1989) indicated that to produce sufficient manure for sustainable production of about 3 tonnes/ha of maize in Ethiopia it required 10-40 ha of dry season grazing land and 3 to 10 of wet season range land, which is beyond the capacity of Ethiopian farmers.

iii) Chemical fertilizers:

The application of chemical fertilizers in Ethiopia is very low, which in average is about 15 kg ha⁻¹. Application of chemical fertilizers is also targeting high value crops (e.g Coffee, tea) and selected farm plots. Low farm productivity in Ethiopia, beyond other factors, is also an indicator of insufficient use of chemical fertilizers. However, chemical fertilizers significantly increased crop yield, particularly if the application was accompanied with organic fertilizers and water management interventions. For example an early research conducted by Holleta research centre in the Ethiopian Highlands indicated that wheat yield could be doubled by application of a combination of only 60 kg N and 26 kg P per hectare (Table 1). The effect is highly pronounced when forage legumes were integrated into the cropping system.

Fertilizer sub-plot	Wheat after vetch (kg ha ⁻¹)	Wheat after wheat (kg ha ⁻¹)
N0P0	2840	940
N0P26	3050	990
N20P0	2910	1040
N30P26	3630	1830
N60P0	3120	1530
N60P26	4550	1960

Mean	3350	1380
LSD (0.05)	800	1590

Table 1. Effects of different rates of nitrogen and phosphorus fertilizers with or without green manuring on wheat grain yield at Holleta, Ethiopian highlands (After Asnakew, 1989).

As indicated in Table 2, crop rotation, particularly integrating forage legumes in to the cropping systems improved fertilizer efficiency by 3 xs. Wheat yield after vetch was almost triple compared to wheat after wheat, though there is an additional opportunity costs incurred by farmers while growing vetch during the growing season replacing wheat.

In general, there is an increasing trend in use of mineral fertilizer in the Ethiopian highlands over the past decades, and fertilizer imports into the country have increased from 47000 tonnes N & P in 1993 to 137 000 tones in 1996 (Quinones et al., 1997). It was mainly as a result of a strong institutional campaign of Sasakawa-Global 2000 in collaboration with the national institutions. However, resource poor farmers are challenged to invest on chemical fertilizers due to the increasing cost of fertilizers, lack of credit opportunities to resource poor farmers and low returns from agricultural produces.

4.3 Varietal mixtures for efficient use of resources

Maize mixtures of early and mid-late maturing cultivars in which there is only a short gap between the tasseling date of the late cultivar and the silking date of the early cultivar yielded 60% more than pure stands in drought years, but only 30% more when there was more rain. The yield advantage was partly because the silk of the early variety remained receptive long enough to be fertilized by pollen from the late maturing variety. Varietal mixtures was found to minimize risk of crop failure and even increased grain yield under drought prone conditions due to improved pollination, as the silk of the early maturing maize variety may remain receptive long enough to be fertilized by pollen from the mid-late maturing varieties (Amede, 1995). The compensation effect could be also enhanced by efficient use of resources as varieties of various maturity period and growth habit may have differential demands for water, nutrients and sun light at a given time and space. The most apparent yield advantage of mixtures over sole crops was their potential to produce relatively higher yield when they were grown under low soil fertility conditions, which was much higher than the early maturing variety at all conditions, and yielded much higher than late maturing varieties under low soil fertility and stress conditions (Amede, 2004, unpublished), a strategy that could be used by small scale farmers to minimize risk of complete crop failure. There was a possibility of minimizing competition in water and nutrient use as the timing of the two components in resource demand may differ. Experiences from other crops also showed that intra-specific mixture of varieties often yield more than pure stands (Panse et al., 1989).

Moreover, growing maize mixtures of different height and maturity period may create a spatial and temporal niche for planting forage legumes as intercrops. The niches could be created when the early maturing component are dead or removed that leaves free space among the late maturing plants for planting of a new intercrop, and/or allowing better growth of early interplanted intercrops once the critical demand of the early variety declines. The benefit could also be enhanced due to better light interception of the intercrop due to differential plant heights of the mixtures.

4.4 Approaches for scaling-up

Participatory approaches are required to demonstrate effects of agronomic interventions and enable farmers to experiment and share knowledge. There is a need to have a continual interaction between farmers and researchers during technology testing to provide insights about potential adoption of new amendments such as in situ water management. The challenge therefore is to impact the idea of integrating interventions to farmers' fields through participatory approaches and have them adapt and adopt alternative organic resources.

Various social groups could adopt or reject technologies based on their own perceptions, experiences, risk carrying capacity and perceived benefits. For instance in Southern Ethiopian highlands, resource-poor farmers resisted the adoption of soil conservation bunds as it would take up land from their small holdings while the rich farmers resisted adopting it due to its very high labour demand. (Amede et al 2006).

Given the complexity of the problem of land resources degradation, and its link to social, economical and policy dimensions, it requires a comprehensive approach that combines local and scientific knowledge through community participation, capacity building of the local actors through farmers' participatory research and enhanced farmer innovation. This approach requires the full involvement of stakeholder at different levels to facilitate and integrate social, biophysical and policy components towards an improved natural resource management and sustainable livelihoods (Stroud, 2001).

5. References

- Amede, T., Lyamchai, C., Hailu, G., et al. 2008. Intensification of crop-livestock systems in East and Central African highlands through adopting integrated approaches. In: Stroud, A., German, L., Mowo, G, Amede, T. and Opondo, C. *Approach matters: Integrated Natural Resource Management in Practice in the Highlands of Eastern Africa*. African High lands Initiative (AHI). In preparation.
- Amede, T., Kirkby, R. and Stroud, A., 2006. Intensification pathways from farmer strategies to sustainable livelihoods: AHIs' experience. *Currents*: 40/41: 30-37. SLU, Sweden. September 2006.
- Amede, T. and Kirkby, R. 2004. Guidelines for Integration of Legume Cover Crops into the Farming Systems of East African Highlands. Pp 43-64. In: Bationo, A., 2004. *Managing nutrient cycles to sustain soil fertility in Sub-Saharan Africa*. Academic science publishers. 608 pp.
- Amede, T., 1995: Yield gain and risk minimization in Maize through cultivar mixtures in semi-arid zones of the rift valley in Ethiopia. *Experimental Agriculture* 31, 161-168.
- Asnakew, W. The role of soil fertility management in crop production. In: *Proceedings of the first Natural Resources Conservation Conference*. IAR, Addis Ababa: pp. 65-72.
- Fatondji, D., Martius, C., Biellers, C.L., Vlek, P.L.G, Bationo, A., Gerard, B., 2007. Effect of planting technique and amendment type on pearl millet yield, nutrient uptake and water use on degraded land in Niger. In: Bationo A. (Eds)_ *Improving human welfare and environmental conservation by empowering farmers to combat soil fertility degradation*. African Soils Network (AFNet). Springer Verlag. pp. 179-193.
- Giller, K.E. 2002. Targeting management of organic resources and mineral fertilizers. Can we match scientists' fantasies with farmers' realities ? p: 155-171. In: Vanlauwe, B., J. Diels, N. Sanginga and R. Merckx, 2002. *Integrated plant nutrient management in Sub-Saharan Africa: From Concept to practice*. CABI International UK, 2002. 352 p.
- Hagos, F. G. Makombe, R. E. Namara, and S. B. Awulachew. (forthcoming). *Importance of Irrigated Agriculture to the Ethiopian Economy: Capturing the direct net benefits of irrigation*. Research Report. International Water Management Institute.
- IWMI. 2007. *Water for food and water for live: A comprehensive assessment of water management in Agriculture*. David Molden (ed.). Earthscan. Pp. 645.
- Murwira, H.K., P. Mutuo, N. Nhamo, A.E. Marandu, R. Rabeson, M. Mwale and C.A. Palm, 2002. Fertilizer equivalency values of organic materials of differing quality. In: Vanlauwe, B., J. Diels, N. Sanginga and R. Merckx, 2002. *Integrated plant nutrient management in Sub-Saharan Africa: From Concept to practice*. CABI International UK, 2002. 352 p.
- Panse, A., H.C. Davis, and G. Fischbeck, 1989: Compensation induced yield gains in mixture of common beans. *Journal of Agronomy and Crop Science* 162, 346-353.
- Quinones, M., N.E. Borlaug, and C.R. Dowsell, 1997. A fertilizer-based green revolution for Africa: In: *Replenishing soil fertility in Africa*. SSSA special publication number 51, 81-96.
- Roose, E., Kabore, V., Guenat, C., 1999. Zaï practice: a West African traditional rehabilitation system for semiarid degraded lands, a case study in Burkina Faso. *Arid Soil Res Rehab* 13(4), 343-355
- Sandford, S.G., 1989. Crop/ Livestock interactions. P. 169-182. In: *Soil, crop, and water management systems for rain fed agriculture in the Sudano-Sahalian zone*. *Int. Crops Res. For the Semi arid tropics*, Patancheru, India.
- Stroud, A. 2001. *Sustainable INRM in practice, Ethiopia*. AHI phase III planning report. Kampala, Unpublished.
- Vanlauwe, B., J. Diels, N. Sanginga and R. Merckx, 2002. *Integrated plant nutrient management in Sub-Saharan Africa: From Concept to practice*. CABI International UK, 2002. 352 p.

