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Missing linkage in rainfall-runoff-soil water relationship for sustainable watershed development: A case study around Hirna, Eastern Ethiopia

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Abstract

Ethiopia is a land with array of watersheds arranged in the ideal conditions and they require systematic evaluation for land suitability to specific use on sustainable basis. Amensis sub-catchment of Hirna watershed in the western Hararghe region of Ethiopia is developed on basalt at the top followed by sandstone and partly limestone at the base. The soil types and basaltic soil materials are remarkably very permeable. There is ample scope for water seepage from the hills and mountains of basalt. Identifying the factors related to water infiltration, means of seepage, ground water recharge, rise in water table, river water storage, zeolite and zeolitic structures in soils, lateral and vertical soil water movement, soil friability, structural arrangement, cracking tendency following oblique slickensides, krotovinas, soil-water retention, hydrologic cycle, cyclic changes in soil water content, weathering of basalt in reduced environment and clay-organic matter interactions is some of important prerequisite in inventorying the resource for soil water management as well as assured irrigation to crops on site-specific basis. Construction of dam in the existing drainage channel would not only harvest the surrounding water, but also act as a buffer in order to promote the soil water status for crop utilization. Necessary technology generation will also include fish culture in order to provide additional economic benefits.

Key words: Highlands of basalt, hydrological cycle, irrigation, rain water harvesting and storage.

Introduction

Rainfall is purely a natural phenomenon almost beyond the scope of human intervention until now, whereas runoff is largely the product of the interaction of rainfall with many factors over the land surface. The soil water by itself is a dynamic state of soil being dictated largely by hydrological cycle. Erratic trend of rainfall makes all related phenomenon very uncertain, but our approach in agricultural development is to make the thing certain and timely. What is important is to make uncertain natural resource certain for exploitation and utilization for crop production. This is feasible by creating an environment for water resource development– surface water, water harvesting and underground water resources. Rain water harvesting for domestic purpose is easy to do, since limitations can be easily managed and controlled, but its storage for other purposes like agricultural uses is difficult due to involvement of many factors, which are difficult to manage. Obviously, the first task in this exercise is to inventorize the environment associated with overall rain water harvesting in order to develop some effective working strategy for assured irrigation to the crops and drinking water to the cattle.

Water, as a growth and yield controlling input, contributes significantly to the overall crop management strategies. Without assured irrigation, improved crop production is often at risk. Any aspiration for maximum crop yield depends on how and in what way water for irrigation is provided. Even the fertilizer efficiency is significantly enhanced with assured irrigation. Providing irrigation is an essential part of the package of practices for a given crop and not just an additional option. In Ethiopia, such important option particularly in the highlands of basalt is least understood and discovered. Most of the related statements follow some internationally established references and hardly suit to the site-specific problems. Present report is intended to discover some scientific facts related to feasibility of irrigation water on highlands of basalt occurring frequently in the western Hararghe region of eastern Ethiopia. Mishra *et al.* [6, 7] and Gebrekidan [3, 4] have outlined and discovered some basic facts related to the natural resource management in the Ethiopian highlands. Such information on site-specific basis is meager. However, the information would be useful to many areas of the country including adjoining African countries where environments are similar.

Materials and Methods

The study area was identified in the Amensis sub-catchment around 9°13.177’N latitude/41°4.955’E longitude and 9°13.610’N latitude/41°5.129’E longitude. The mean annual rainfall of Hirna is about 1000 mm with heavy rain mostly in July, August and September. Rock species and their arrangement were identified during free survey of the catchment. The depthwise soils were characterized in toposequences. The crop performance on sloppy land of the mountain and plain areas of topographic lows was recorded during the free survey. The seepage of water from mountains and underground water levels were monitored by traversing the area through farmer’s interactions between Kulubi and Bedessa with emphasis on Hirna area. Minerals like zeolite were identified using X-ray diffractograms for clay and silt samples as well as during collection of the samples during survey. Relevant chemical and physical data were used from elsewhere under the projects for interpretation.

Results and Discussion

Specific soil water related inventories: The Amensis sub-catchment is bounded with many hills and mountains of definite petrologic arrangement. The basalt occupies its position on the top about more than 100 m of its thickness, wherein bottom is mainly the sandstone with some broken thin strata of limestone. The soil occurs throughout the watershed starting from the top to the bottom of the mountains in varying depths. Basalt, in general, occurs in its fragmented morphology having permissible passage for water to move downward. The backslope with slope gradient of more than 50 percent normally indicated shallow soil depth following sometimes to exposure of rock outcrops.

Rain water penetrates through the inter-fragmental space/ passage (interstices) of basalt and sometimes in case of other rock species particularly sandstone also and facilitates further weathering beneath the surface of soils. Even on the top of the hills and mountains of basalt, soils so developed are clayey in texture, crumb to granular in structure with very high rate of permeability. Accordingly, the soils themselves are capable of allowing rain water to move downward rapidly. Both soils and associated parent materials facilitate rapid downward movement of rain water allowing little time for water to either evaporate or to flow as run-off. This is a reason that the soils developed on basalt are more water absorptive and resistant to erosion and even the top and backslopes of basalt mountain give more greenery look as compared to mountains developed on other rock types (Plate 1). Another typical example of vegetative cover on basalt is shown in Plate 2, where basalt is on the base of white sandstone.

The clay minerals occurring in such soils indicate the presence of zeolite or zeolite-type minerals, which are known to act as molecular filters and permit water molecules to pass through their structures easily [6]. Zeolite has been identified in Hirna in the Gora Sera mountain (Plate 3). Presence of the zeolitic structures in soil facilitates water movement even in soils containing very high clay contents (>60%). Probably due to their presence, the heavy clay soils are well to excessively well drained. Once the rain water moves down the soil, it keeps up moving down (Plate 4) until weathered parent material (basalt) reaches some consolidated stratum and the water gets stored, if some cavity has formed in the mountain (Plate 5). In the absence of such cavity, the moving water gets out of the mountain through seepage or directly enriches the ground water recharge through its downward movement.

Reduced environment is recorded to be somehow favourable for the weathering of basalt ($Fe_2O_3 \rightarrow FeO$) and become soft even by hydration process ($Fe_2O_3 \rightarrow Fe_2O_3 \cdot 3H_2O$). This was evident with the fact that the weathering of basalt was more intense, where the water gets accumulated beneath the unweathered or partly weathered rock and the rock below the surface looks more weathered as evident from the change in their colour and texture/ morphology (Plate 4). Such weathered basalt gets slowly removed through some seepage and perhaps creates a huge spongy cushion in the basalt mountain in due course of time, where water gets more space to accumulate as well as gets saturated with weathered basalt. It was also observed that basalt weathers until the size of clay and thus holds water in its colloidal size (Table 1). This mechanism thus facilitates the weathering of basalt in the closed system and transforms into clay-sized minerals including amorphous materials, which have high water holding capacity. The products of basalt weathering further undergo interaction with organic matter in the system, if present, since clays being transformed and altered from basalt are mostly of expanding clays including smectites (unpublished), which are very sensitive to react with organic molecules in the given system. Such mechanisms consequently promote collectively not only the absorptive capacity of their products but simultaneously enhance the permeability in order to facilitate downward movement of water.

The drying of some lakes, Alemaya lake for example, is not just due to siltation/sedimentation through erosion alone, but importantly more so due to continuous reduced environment causing weakening of underlying rocks and substratum that

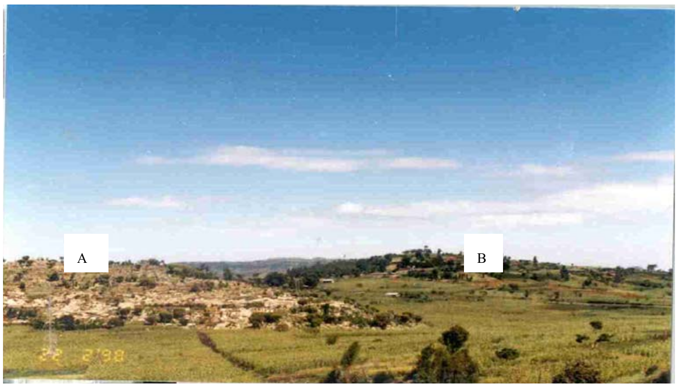

Plate 1. Limestone Wolex hill (A) in close proximity to basalt Hedabu hill (B) in Chelenko Lola (PA Chelenko) with distinct land use pattern (N 9°24’59.2" latitude, E 41°37’22.5" longitude, 2179 m altitude). Slopes being almost identical, limestone (white) appears as rock outcrop whereas basalt is covered with vegetation.

Plate 2. Basalt (zeolite containing) on white sandstone. Basalt shows soils in which vegetation is distinctly seen (A) whereas sandstone has only sparse vegetation (B). Besides, the slope of basaltic landscape is gentle whereas sandstone indicates steep slope. (N 9°25’ 41.5" latitude, E 41°39’7.6" longitude, 2354 m altitude) in Duse (Meta) of Kulubi. The whole mountain series (Simbro) also releases water through seepage, temporarily during rain. Water is available at the bottom.

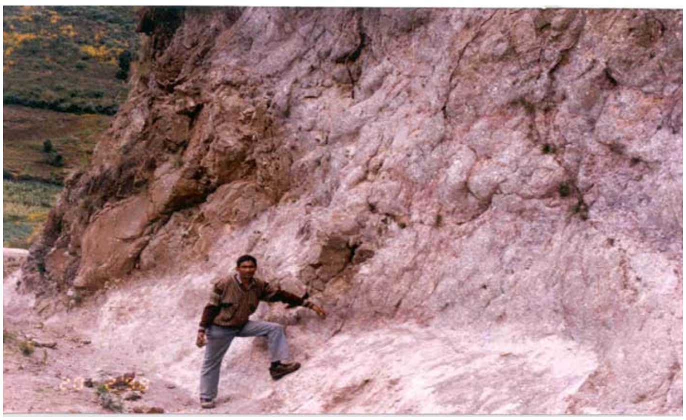

Plate 3. Basalt mixed with zeolites in Gora Sera mountain at Gande Habte (Oda Nagaye PA) in Hirna (N 9°15’ 35.2" latitude, E 41°6’47.5" longitude, 2243 m altitude).

Plate 4. Basalt getting reduced in water stored through seepage at Gera in Hirna (N 9°15’53.1" latitude, E 41°6’20.8" longitude, 2191 m altitude).

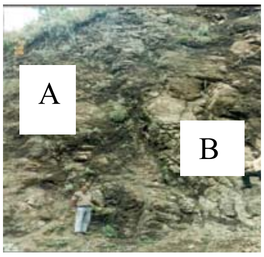

Plate 5. Basalt mountain (Wolergi) showing wetness (A) where intense weathering could have made the rock more unconsolidated as compared to the relatively more consolidated basalt (B) at Gande Gode in Worolgi (Knni). Wetness shows dark gray to greenish colour (A) whereas dryness indicates white colour (N 8°58’12.1" latitude, E 40°50’24.7" longitude, 2154 m altitude).

facilitates downward movement of the stored water in the lakes. Folded rocks with fractures and possible clay mineral transformation during reduction under inundation are also some of the reasons for water to move downward leaving lakes empty of water. Fine sandstone stratum with appreciable iron content giving reddish tint was seen to be more weatherable in the rock strata probably through the process of reduction and hydration.

The soil particles, which are, even somehow hard when dry, become very friable just on adding a few drops of water. Such easy friability of soils indicates the immediate contact of water molecules with the inner soil surface until saturation. Here, the contribution of organic matter may also not be overlooked. However, such friability by itself indicates easy entry of water into the soil mass. It is recorded that the continuous rain for hours together would not cause waterlogging even in the most depressed areas of the topographic lows. Such easy entry of water into the soils is also facilitated by the soil structural make-up. Most of such soils have definite structural arrangements such as granular or crumb on surface followed by blocky with general tendency to develop prismatic structure at the bottom of the profiles. The presence of shining coating on ped faces, krotovinas (open channels due to biotic factors) and cracking features is additional evidence of high permeability in soils. These properties at the bottom of profiles terminate with appearance of obliquely oriented slickensides showing polished surfaces on fracture planes without any sign of mottle. These are the thumb of rules for rapid infiltration of water into the soils (Plate 6), although the clay content in the soils were even more than 75 per cent, which might have restricted the infiltration rate as per existing knowledge. Plate 7 is a profile of Fluvisols of Alemaya showing clear stratification with platy structure causing poor drainage with appearance of mottles in the sub-soil horizons. Of course, such platy structures were not recorded in Hirna catchment.

During dry season, the crops including maize, sorghum and even *Chat* perform better on the shoulders and sometimes gentle backslopes of the basaltic mountain even as compared to the depressed low lying plain areas. Interrogation with the farmers revealed that the crops in soils of the shoulders and/or backslopes are better supplied with water as compared to low lying areas particularly during dry season. A survey to this effect further revealed that the soils of low land are deep to very deep enough to moisten the soils in their series control section (25-125 cm) appreciably. On the other hand, water stored or even soaked in the mountain or simply entrapped in basalt fractions could be able to keep the soils of the sloppy landscape moistened for some time to its plant utilizable level during dry season, whereas deep soils in low lying area get dried up on the surface. The soil moisture

Table 1. Mean values of the mechanical composition in different pedons arranged in toposequences.

Toposequence	Pedon	Sand (%)	Silt (%)	Clay (%)	Texture
1, Backslope	1	57.23	20.85	21.29	sil
1, Backslope	2	55.56	21.28	23.16	sil
1, Toeslope	3	29.89	19.52	50.59	c
1, Foothill	4	14.06	22.96	62.98	c
2, Upland	1	4.16	17.17	78.67	c
2, Midland	2	5.36	17.42	77.22	c
2, Lowland	3	3.68	17.95	78.37	c
3, Foothill	1	13.89	17.19	68.92	c
3, Upland	2	23.36	15.02	61.62	c
3, Midland	3	15.56	10.78	73.66	c
4, Lowland	4	9.23	20.85	69.92	c

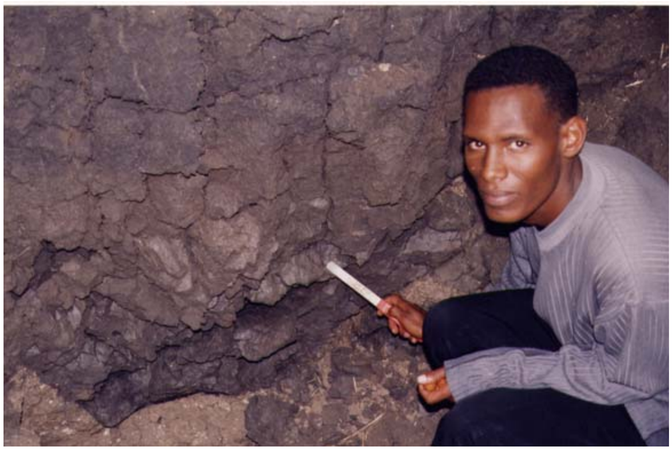

Plate 6. The sub-surface soil showing distinct features of slickenside, shining ped faces and blocky structure(at Alemaya university farm land).

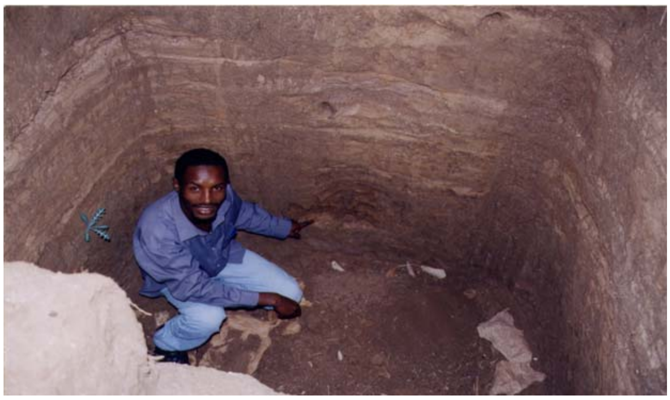

Plate 7. Prominent stratification in a Fluvisol of Alemaya showing platy structure with appearance of mottle in sub-soil horizons.

contents at field capacity and wilting point were around 30 and 20 per cent in most of the soils, respectively. Hence, the available soil water content is only about 10 per cent. Incidentally, much of the water content of soils is not utilizable to plants. This further seems to be of serious concern, wherein proper management option needs to be developed precisely taking into account all possible attributes.

Ground water recharge: It is apparent that there are favourable environment for rain water to enrich the ground water recharge in such a basaltic landforms. However, systematic information on the extent of the ground water recharge is neither well addressed nor discovered systematically. Even the practice of digging wells for drinking water and installation of tube well is virtually at demonstration stage in most parts of Ethiopia. A perusal of data in Table 2 indicates that there is ample scope of ground water recharge even through seepage from mountains. A mean annual rainfall of around 1000 mm particularly in sub-temperate climate is sufficient for ground water recharge.

Field survey in the Amensis sub-catchment of Hirna watershed indicated that the water table during wet (rain) season approached the soil surface, while in dry season, it goes as low as 5-6 m. However, actual figures were not available and there is need to have piezometric data at various locations in order to prepare a hydrologic map. For any watershed development, hydrological description on grid point basis is a pre-requisite.

When the soil body in continuum follows non-soil, which is weathered materials (unconsolidated) or even fragmented rocks (basalt), the water often moves down vertically and the surface soil mass becomes quickly dried and subsequently the crops get wilted. Contrary to this, when the non-soil material is consolidated rocks or some impermeable strata, the lateral water movement is predominant. Such lateral movement of water keeps it fairly close to the surface through capillary rise and plant does not suffer much from moisture stress so quickly. In Hirna watershed, the soils of foothill indicated such vertical movement leaving crops like maize under moisture stress even after a few days of rain, whereas soils of uplands and midland in the plain indicated more moisture than soils down the surface as observed through their relative stickiness due solely to the lateral water movement along the slope. In the low lying plains, however, water movement is vertical in deep soil body and moisture retention in surface soil depends primarily on the depth of water table in order to facilitate the capillary fringe to be close to the plant roots. In case of low water table, surface soils suffer from moisture stress, since capillary fringe could not approach even the root zones. Low water table in plain is primarily due to deep to very deep soils. The soil was found to be even more than 10 m deep in depression and water table has gone down to about 5-6 m deep during dry season.

High rate of water entry into the soil and subsequently downward movement indicate little scope of immediate evaporation as well as runoff from the surface. Apparently, the water received from rainfall is subject to be stored in the ground after equilibrating with soil body. The mean annual rainfall being almost near 1000 mm needs further to be quantified in terms of its contribution to ground water recharge. The rise of ground water level in a given event of rain storm would give an approximate estimate of the sum of evaporation loss, transpiration loss and soil water storage. The rise and fall of ground water levels follow a hydrologic cycle, which can be established by piezometric monitoring. However,

Table 2. Identification of rainwater resource in the mountains around Hirna.

Site	Latitude, N	Longitude, E	Altitude, m msl	Mountain	Place	Peasant assoc.	Special features
Kulubi 1	9°25’41.5”	41°39’7.6”	2354	Simbro series	Duse	Teta	Water seepage permanent in the bottom. Basalt on sandstone containing zeolite.
Karamille 1	9° 22’53.7”	41° 24’18.8”	2073	Gola Lili series	Madisa	Karamille	Permanenet seepage. Korean water supply pump.
Hirna 1	9° 15’23.3”	41° 24’18.8”	2200	Goda Badalu	Odanaggar	Hirna	Seepage being slow in dry season.
Hirna 2	9° 14’14.4”	41° 5’27.6”	1867	Alkai	Alekeya	Hirna	Three water channels meeting emanating from different foothills
Hirna 3	9° 14’19.5”	41° 5’23.3”	1868	Alkai	Haji	Hirna	Water emanating through ground seepage from surrounding hills.
Hirna 4	9° 15’38.2”	41° 6’34.4”	2155	Foyso	Bosona (Abrahim Hassen, farmer)	Reketefura	Ground seepage from surrounding hills in small depression.
Hirna 5	9° 15’36.7”	41° 6’27.0”	2141	Abealeye	Bosona	Reketefura	Water thoughout the year and used mostly for drinking.
Hirna 6	9° 15’28.4”	41° 6’19.6”	2072	Abduta	Abdute	Reketefura	Continuous seepage.
Hirna 7	9° 15’38.9”	41° 6’18.4”	2123	Cheleleke	Abdute	Reketefura	High speed seepage.
Hirna 8	9° 15’53.1”	41° 6’20.8”	2191	Cheleleke	Gera	Reketefura	Temporary seepage during rain.
Bedessa 1	8°59’41.7”	40°52’16.9”	2455	Sororo	Sororo	Kunni	Ten months seepage except Jan. & Feb.
Bedessa 2	8° 59’27.4”	40° 51’49.6”	2372	Lagalaku	Legelafto	Sororo	Whole year seepage. Hill 500 m from seepage point.
Bedessa 3	8° 59’13.0”	40° 51’40.6”	2347	Ansara	Ansara	Sororo	Water stops after rain.
Bedessa 4	8° 58’49.7”	40° 51’5.7”	2235	Babu	Madere	Sororo	Permanent water fall. UNICEF provided permanent structure for drinking water supply.
Bedessa 5	8° 58’12.1”	40° 50’24.7”	2154	Wolergi	Gande Gode	Kunni/Sororo	Side of hill getting wetted due to seepage.
Bedessa 6	8° 52’52.6”	40° 42’13.2”	1728	Saggar (Natural Resource Nursery)	Karakurkura	Karakurkura	Many seepage points during rain. Water table during dry season is 6 m.
Bedessa 7	8° 52’32.5”	40° 41’3.0”	1742	-	Karakurkura	Karakurkura	Water is stored in low lying adjoining area
Kunni 1	9° 0’3.3”	40° 52’58.2”	2509	Muktar & Sabale	Kenso	Kunni	Many seepage points together for whole year, but slow seepage and no river formation.
Kunni 2	9° 2’40.8”	40° 54’39.4”	2299	Mikhael Abrahim, (farmer)	Katena 1	Arbrakete	Govt. sponsored rain water harvesting.

the soil water storage of a given land unit can be established by monitoring the trend of soil moisture retention as well as fluctuation of gravimetric water content of soil on regular basis to prepare a soil moisture cycle for the given land unit in time and space.

All such specific environments related to rain water entries into the soils indicate very strong feasibility of ground water recharge after being escaped from infiltration, saturation, stagnation, evapotranspiration and finally from runoff. Any strategy for watershed development as well as its management would address the ways and means of ground water recharge in order to generate technology reliable to the given landform.

It is apparent based on preliminary survey that there is abundant ground water resource and one has to look sincerely for mountain water reserves also besides harvesting and storing the runoff and using rainfall directly for landuse. The land is not only a sandwich between ground and mountain waters, but equally viable to receive the water that comes through runoff and rainfall. What is needed is to integrate the management efforts to make effective use of these water resources for sustainable production and consequently for generation of the socio-economic standards as shown below in Fig 1. Of course, water resources like rivers, lakes and others have not been considered under such discussion, since they are selective in their occurrence.

Considering rainfall as the only source for ground water recharge, it is wise to identify the factors which interact with rainfall water. The components as shown in Fig. 2 are soil water storage capacity (SMSC), evapotranspiration (ET), interception (I), artificial surface drainage (D), runoff (R) and capillary rise of the water in soil profile (C), which contribute normally to the ground water recharge with lapses of time (T). This expression can be depicted in the following equation:

Total rainfall – (SWSC + ET + I - D + R + C + ————)T = ground water recharge

The soil water storage capacity, capillary rise of water in profile and degree of evaporation/evapotranspiration are almost constant in a given land type. Interception due to surface roughness, surface drainage and runoff can be managed in time (T) and space in order to maximize groundwater recharge. Such equations are based on average values of the respective components and may be used just to understand the possibility of water storage either in ground or mountain. Quantification after refinement of each component for a given land unit would help for practical application.

In time and space, the level (height) of ground water (water table) of the catchment acts as a reference to monitor the changes caused by precipitation. How much amount of rainfall out of actual total precipitation in the catchment would have contributed to bring about change in the height of ground water can be computed for collective contributions from various means like soil moisture storage capacity, evapotranspiration, interception and runoff. By this is meant that precipitation is always subject to interactions with various land features leading to ground water recharge.

Rainfall-runoff relationship: Soil-water-plant relationship under rainfed conditions depends upon hydrological cycle following the inflow and outflow of water over, through and beneath the soil body and plant leaf surfaces to the atmosphere. Rainfall is erratic with varying intensity, duration, frequency and distribution, whereas runoff is that part of rainfall which moves downslope towards stream channels undergoing interaction with soil infiltration, surface detention, soil moisture storage, evapotranspiration, interception by vegetation, steepness of land slope, nature and type of parent material. Relief features, hydrological cycle, vegetative cover pattern, surface features due to micro-depression or even surface roughness, watershed morphology and the underground water storing capacity would have obvious contribution to the degree and magnitude of runoff. The objectives for water resource development are water development for domestic use, surface water development, water harvesting in catchment and ground water development. Evaporation from wet soil surfaces or plant leaves and seepage loss are two main barriers in the surface water development and water harvesting in catchment. The best way is to look for ground water development, which is naturally stored water that is almost non-evaporative. The overall environment in Ethiopian context needs to be examined on location-specific basis. Reference-oriented approach can hardly bring reliable information for effective technology generation. The underground water accounts for about 98 percent of all the stored water of the world and remaining two percent occurs mostly in streams and lakes [1].

Land characteristics by themselves control the effective rainfall dynamics in varying intensities. Infiltrability of soils, which is related collectively to different soil properties like textural and

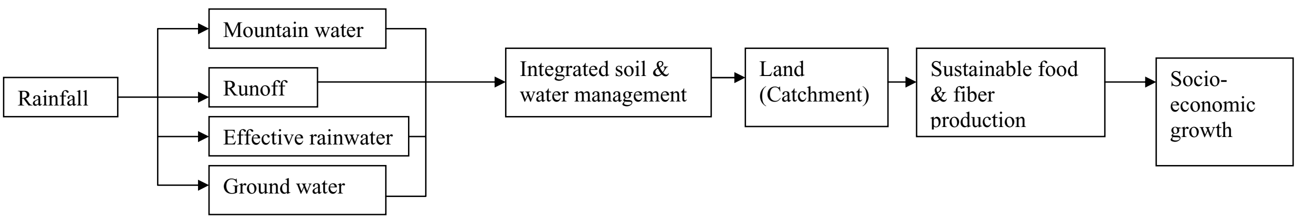

Figure 1. Natural water resources in Ethiopian landscape developed on basalt.

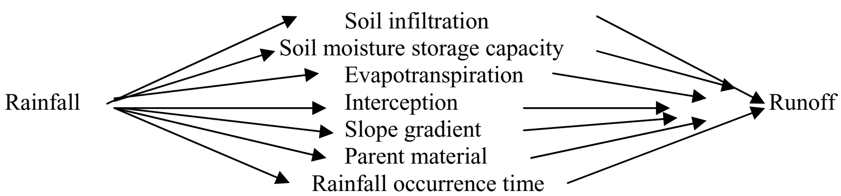

Figure 2. Rainfall-runoff relationship in a catchment.

structural make-up, bulk density, organic matter status and soil consistence, in association with soil moisture storage capacity, interception and evapotranspiration, influences the runoff negatively, whereas land slope and rainfall occurrence time contribute to runoff variably (Fig. 2). Parent material, however, also contributes to runoff very selectively. Basalt, for example, develops a soil which resists runoff yield relative to other parent materials. Limestone derived soil particles are susceptible to water erosion and so to runoff. With the identical slope gradient, limestone derived soils get more eroded than that of basalt due to their fine-sized particles bound chemically with organic molecules probably Ca humate.

The seepage water from the surrounding basaltic mountains is getting released at various points in the channels (Plates 8 and 9). Such seepage water is the only source for domestic purposes (Plates 10 and 11). At some locations, the seepage water appears as a small water fall (Plate 12) terminating to a common water channel (Plate 13 and 14). All of them are some relevant supporting evidences in relation to the facts recorded in the Hirna catchment as well as adjoining areas for inventorying the rainwater resources. There is thus need to make use of such valuable resources even at the micro-level. Many of the seepage points discharge water continuously with varying intensity throughout the year and need to be exploited for sustainable uses through conservation, management and water harvesting. Many of these seepage waters meet together to form a big water channel. The rock arrangement in the structure of the mountains dictates the possible passage of water entry into and through the mountains as well as rocks to cause seepage.

Watershed development and water harvesting: Watershed is truly a geo-hydrological unit of the landscape having common drainage point. By this is meant that the surrounding of the landscape must be the upland or uphill with slope direction towards a common drainage point in depression located somewhere in the center so that the rain water may move from the topographic highs of the landscape to topographic lows and terminating at the common drainage point. Most of the landscapes in Ethiopia form distinct and ideal watersheds. Plate 15 is a rainwater harvesting technique at micro-level to be popularized among farmers by the federal government of Ethiopia.

Amensis sub-catchment is also a part of similar watersheds surrounded with topographic highs in the form of hills and mountains. Hirna River is the common drainage channel which emanates from different surface and sub-surface seepage points of the basalt mountains and carries the runoff during rain. However, only sub-surface seepage water through the mountains appears in the river during dry season. No effort has been made to utilize this water for watershed development. Farmers are willing to make use of such mountain water scientifically in their cultivation (Plate 16). However, in the depressed plain area, where water is coming from different sources, watershed development and management are not addressed at the grass root level. The following steps may be some site-specific key options for technology generation in the depressed plain area of watershed

❖A simple dam needs to be constructed to stop the wastage of river water during rainy season. The excess water, which may adversely affect the low lying plain area by flooding, may be released out of the river channel through the water release mechanism of the dam. By this is meant that water must be stored to full capacity of the river/channel. The construction of dam in Hirna river channel (drainage point) would actually enable the water to be stored in river channel leading to slowing down the seepage rate of water from whatever is the source in the adjoining mountains/hills. This condition would help keep the soils even on the uphills and sloppy lands with better moist and humid environments in time and space.

❖Storing water would cause lateral water movement throughout the plain area of watershed and would keep the soil water more available to crops. Lateral water movement is facilitated by the inherent soil properties themselves as discussed elsewhere.

❖The water table would virtually be intended to rise appreciably due to the impact of stored water in the river channel. This will keep soils to be better supplied with water, since the permeability of most of the soils is appreciably good to let the water flow in soils laterally and vertically.

❖Using some pumping mechanism, the channel water can also be used for irrigation directly to the adjoining fields to fulfill the water requirement of the crops. Obviously, crop selection would be the first priority for cultivation in the watershed. Most valuable crops of high water requirement including vegetable crops and rice would be cultivated preferably in the close proximity to the river channel. Rice cultivation may be introduced successfully to get more return as compared to crops like sorghum, tef and even maize.

❖Fish culture would be important and aspiring preference to be introduced in the river channel according to the period during which water is sufficient in the channel. This activity would lead to additional income generation on cooperative and participatory basis.

❖To reduce the evaporation from free water surface, minimizing the surface area to volume ratio is one simple way and use of monomolecular films (fatty alcohols like hexadecanol) or floating membranes (butyl rubber) are often practiced. There are many other practices to minimize the evaporation, but it is not easy to handle without proper technical and financial support to the user community.

The above soil water related technology mission would follow the scientific way of watershed development through relevant conservation as well as management activities. In the concept of watershed, it is obvious that the drainage channel as per definition has to be reshaped into an irrigation water source. This source, having stored water, would virtually act as a “buffer” to resist the soil water depletion and, as a consequence, it will appear as a means to promote the water use efficiency not only in the low lying plain lands, but will also indirectly help restoring the soil moisture status of the hill tops and bottoms including slopes due to the integrated effect imposed by overburden pressure potential, wetness potential and air pressure potential. The relative humidity caused by the water in the surrounding also contributes to the water dynamics in the system. When the distance between the water table and the soil surface is high enough, the coarse textured soils offer more resistance to upward flow than do the finer textured soils. Besides, the upward water flow nearly drops to zero as the wetting front reaches the coarse sand layer because there is little water in fine pores in the sand and the larger pores cannot fill at the low matric potentials present in the upper region [5].

One land with large area in the watershed is owned by many persons, who are of different socio-economic backgrounds. This

Plate 8. Alkai river at Alekeya in Hirna collecting water being discharged from surrounding basaltic mountains through seepage (N9°14’ 19.5" latitude, E41°5’23.3" longitude, 1868 m altitude).

Plate 9. Seepage of water through soil in the foothill of Alekeya mountain of Haji village in Hirna (N 9°14’14.4" latitude, E 41°5’27.6" longitude, 1867 m altitude).

Plate 10. Water seepage from basalt in the foothill of Abealeye mountain in Reketefura PA in Hirna mostly used for drinking throughout the year (N 9°15’ 36.7" latitude, E 41°6’27.0" longitude, 2141 m altitude).

Plate 11. Drinking water being collected from seepage water of Foyso mountain near Bosona in Hirna (N9°15’28.4" latitude, E41°6’19.6" longitude, 2072 m altitude).

Plate 12. Small water fall from foothill of Celeleke mountain in Gera of Hirna (N 9°15’38.9" latitude, E 41°6’18.4" longitude, 2123 m altitude).

Plate 13. Water from different mountains meeting to Alkai river at Alekeya in Hirna (N 9°14’ 14.4" latitude, E 41°05’27.6" longitude, 1867 m altitude).

Plate 14. Upwelling of seepage water in a small depression continuously throughout the year, at Bosona in Herna (N 9°15’38.2" latitude, E 41°6’34.4" longitude, 2155 m altitude).

Plate 15. Farmer (Mikhail Abrahim) working on rainwater harvesting at Katena Andi (Arbrakete) near Kuni in 15 m x 15 m x 2 m pond (N 9°02’40.8" latitude, E 40°54’39.4" longitude, 2299 m altitude). The programme is sponsored by the Ethiopian Government. The bottom of the pond is covered with plastic to minimize seepage loss and side is planted with castor to minimize evaporation by shadowing.

Plate 16. Seepage water appearing from the ground in the small depression at mountain shoulder from where water is flowing towards Alkali river at Bosona (Reketifura) in Hira. Foyso mountain releases this water throughout the year. Abrahim Hassen (farmer) is managing this water for micro-level irrigation (N 9°15’38.2" latitude, E 41°6’34.0" longitude, 2155 m altitude).

imposes very difficult situation to integrate the approach on participatory basis under some accepted federal frameworks. Hence, the practical approach to the development of a watershed needs multidisciplinary planning under an approved government policy. The Ethiopian Federal Government should take a pledge to ensure irrigation by encouraging watershed management program. Without assured irrigation, production through high yielding crop varieties would remain rather a dream in spite of large arable potential lands.

Conclusions

Rain water harvesting, in its holistic perception, is a mechanism or even a process or technology to store water in order to fulfill our domestic as well as other demands including agricultural and livestock production. Water is next to air for human and animal survival and assuring water in the water-stressed condition is not only vital, but most critical both for animal and plant lives. Under Ethiopian condition, this is the most attractive means through which we can assure irrigation to the crops and water for livestock including domestic uses in the watershed.

Rainfall-runoff-soil water relationships are very complex and numerous factors are associated to define such relationship from natural system to anthropogenic activities. Obviously, we need to synchronize the system wisely before we start any intervention.

Preparation of very selective type of inventories for watershed development, nature of ground water recharge and construction of suitable dam in the drainage channel of the watershed would collectively ensure the availability of irrigation water and promote the water use efficiency in the watershed. In addition to already known inventory and related information, the conditions discovered are the pre-requisite to the key factors for a successful watershed development and desired technology generation in soil water management thereof. However, the principles need to be validated for application on national and international basis in order to sustain the scientific merits. Importantly, the management options must be flexible to cope with the surplus and deficit of water and, therefore, integrated efforts are required where all relevant environments are taken into consideration simultaneously in the decision making process.

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