PRODUCTIVE LAND USE SYSTEMS
HAITI

SOUTH-EAST CONSORTIUM FOR INTERNATIONAL DEVELOPMENT

AND

AUBURN UNIVERSITY

52, Rue Mangones
Berthé, Pétionville, Haïti
Tél.: (509) 57-1022
(509) 57-0969
Fax.: (509) 57-3962

International Mailing Address:
c/o Lynx Air
P.O. Box 407139
Ft. Lauderdale, FL 33340
U.S.A.

SECID

HAITI PRODUCTIVE LAND USE SYSTEMS PROJECT

SOUTH-EAST CONSORTIUM FOR INTERNATIONAL DEVELOPMENT

AND

AUBURN UNIVERSITY

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Water Harvesting
and Small-Scale Irrigation

by

Kyung H. Yoo
Department of Agricultural Engineering
Auburn University

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EXECUTIVE SUMMARY

The objective of this consulting work was to develop recommendations for water harvesting systems development in the Northwest Region of Haiti for the BIG project and for livestock watering. The consultant also observed the currently used conservation measures from engineering viewpoints such as structure, strength, design and installation.

The following interventions for water harvesting and soil/water conservation were observed in the three CARE regions:

a. Biointensive Garden (BIG) projects.
b. Rock wall check dams.
c. Hedgerows.
d. Roof runoff catchments.
e. Roadside runoff catchments.
f. Springs.
g. Irrigation projects: head works and canals.
h. A large scale hill-side runoff catchment system (approximately 30 m by 30 m) in Passe Catabois.

Any water harvesting systems (either from field or roof) in the Northwest region will offer various benefits: 1) water for irrigation, livestock, and other beneficial uses; 2) reducing runoff and erosion in ravines; and 3) recharging aquifers in the region. The first benefit will provide direct incentives to the BIG participants and others who build water harvesting systems and the other two will provide a long term benefit to the region and the country.

The climate and landscape of the region seem to be adequate for water harvesting systems and demand for such water sources is high. It was observed that many villagers were interested in the BIG project. Success of the BIG project would rely on good water sources for irrigation and livestock as well as the participants' strong will.

In general it is feasible to harvest water from roofs, roadsides, and hill slopes in the three regions visited during the consultancy. A roof catchment system is proposed for the Northwest Region. It is similar to the existing systems in the region but with a few modifications. In Bombardopolis and Passe Catabois regions, large scale community-based water harvesting systems (over 1,000 m^3 water holding capacity) could be developed should pond sites be available.

Construction of water holding dams for irrigation in streams and rivers would be ineffective under the current severe sedimentation problems. Any large scale irrigation schemes in the area should be considered only after conservation measures show

evidence of reduction of hill side erosion and lower sediment loads in the streams.

Soil conservation and erosion control can be achieved by any field practices which reduce the erosive forces of runoff from hills and erodible field conditions. Overall the PLUS project seems to be working in the right direction and has been achieving its objective of conservation by mitigating erosion problems while providing incentives for the participating farmers. However, some problems and drawbacks exist in the gully control and the BIG component of the project. In the Northwest Region many ravines have been badly damaged by past erosion that it may not be feasible to protect the gullied areas from further expansion without implementing extensive conservation measures such as gabions or concrete structures.

The efforts of the PLUS project would be more successful by further emphasizing the conservation measures on the primary source areas of erosion-causing runoff. Erosive forces of runoff would be reduced by controlling runoff from hill tops, hill sides, and newly developed shallow ravines. Gully-control check dams should be strengthened with rocks behind the vegetative plugs and hill sides protected with rock walls.

Reduction of runoff is the first step to control most erosion problems and it should be done from the top of hills. It may take more areas to deal with than controlling runoff in gullies but it is technically less difficult. Any field practices and systems which reduce runoff and its concentration from hill tops and hill sides would reduce the erosion potential by reduced erosive forces of the runoff. Successful conservation measures will directly benefit the participants with better soil and more water retention and will also benefit the region and the country as a whole with reduced expansion of gullies, increased aquifer recharge, and less sediment loads in the valleys.

Good maintenance of water harvesting systems is of utmost importance as well as design and construction of the systems. Proper compaction of pond soil can effectively seal pore spaces which results in reduced seepage losses. Seepage rates are further reduced with clay, ash, or animal manure which is spread on the pond bottom and mixed with the soil before compaction. Inspection and necessary maintenance should be done after major storm events. Maintenance should include; cleaning of sediments from sediment trap and pond, repairing of washed areas, and additional compaction should seepage increased.

The following systems and practices are recommended for immediate or future implementation for improved performance and outcome of the BIG and PLUS projects.

a. Field water-harvesting systems with ponds for multi-ownership BIG project such as one in Bombardopolis and roof-runoff catchment systems for single family ownership BIG projects. The water collected from roof catchment may be safely used for domestic purposes. Schematics of these structures are given in Appendices. Brief concept of the design was discussed with the personnel in the regional office.

b. Training workshop on small scale irrigation and irrigation scheduling for the BIG project participants through training of regional office personnel.

c. Installation of rock walls and hedgerows in shallow ravines and check dams in gullies. Design details of these structures are shown in Figures 1 and 2. Brief concept of the design was presented to the personnel in the regional office.

REZIME

Objektif travay konsiltasyon sa-a se pou bay rekòmandasyon pou devlope sistèm pou ranmase dlo lapli nan Nòdwès peyi Dayiti pou fè jaden legim ak pou fè elvaj. Konsiltan-an te obsève tou mwayen ki itilize nan Pwojè-a pou kenbe tè ak dlo lapli. Kòm enjenyè, li gade si estrikti yo solid, si yo te byen chwazi, byen planifye, si yo te byen fèt.

Nan twa (3) rejyon CARE ap travay, men ki teknik pou ranmase dlo lapli ak pou kenbe tè ak dlo konsiltan-an te obsève:

a. Jaden legim (BIG: jaden byoentansif)
b. Mi sèk nan ravinn
c. Ranp vivan
d. Dal pou ranmase dlo lapli
e. Dren-kanal bò rout
f. Sous
g. Estrikti irigasyon: baraj nan tèt sitèm nan ak kanal yo
h. Yon gwo sistèm (30 mèt pa 30 mèt konsa) pou kapte dlo lapli nan Paskatabwa.

Nenpòt ki sistèm pou ranmase dlo lapli (sou tè yo oubyen sou tèt kay) ki fèt nan Nòdwès-la ap genyen pliziè avantaj: 1) ap genyen dlo pou aroze plant, pou bèt, k-ap sèvi pou lòt bagay ankò; 2) dlo k-ap desann ak erozyon nan ravinn ap diminye; 3) ap genyen plis dlo anba tè nan rejyon-an. Premye pwen-an se yon avantaj dirèk pou moun k-ap fè jaden legim yo. Lòt de pwen yo se yon avantaj alontèm pou rejyon-an ak peyi-a.

Klima ak peyizaj rejyon Nodwès-la sanble ta favorab pou etabli sistèm pou ranmase dlo lapli. Genyen anpil demand pou dlo. Sanble tou anpil moun enterese nan jaden legim. Pou gen siksè nan fè jaden legim non sèlman fòk patisipan yo gen bòn volonte men fòk yo jwenn dlo pou aroze jaden-an ak pou bay bèt.

Anjeneral li posib pou ranmase dlo ki soti sou dal kay, bò rout, ak sou mòn nan tou le twa rejyon konsiltan-an te vizite. Konsiltan-an pwopoze yon sistèm ranmase dlo sou dal pou rejyon Nòdwès-la. Se menm sistèm ki egziste deja-a ak kèk ti chanjman. Nan zòn Bonbadopolis ak Paskatabwa, se posib pou fouye gwo basen pou ranmase dlo lapli pou sèvi kominote-a (yon sistèm ki ka kenbe apeprè 1.000 mèt kib dlo).

Li pa rekòmande pou konstwi baraj irigasyon sou rivyè akòz gwo pwoblèm debri (sediman) ewozyon charye soti nan mòn yo. Tout gwo sistèm irigasyon nan zòn nan ta dwe fèt sèlman lè yo fin pwoteje mòn yo kont ewozyon, lè gen mwens sediman ki vinn tonbe nan rivyè yo.

Kontwòl ewozyon ak konsèvasyon sòl kapab fèt ak nenpòt ki

teknik ki ka diminye fòs dlo k-ap desann nan mòn yo e ki anpeche tè-a ale fasil. Anjeneral, Pwojè PLUS sanble ap travay nan bon direksyon-an e sanble ka reyalize objektif konsèvasyon li yo paske nan chèche rezoud pwoblèm ewozyon yo li konsidere avantaj ekonomik pou patisipan yo. Sepandan, genyen kèk pwoblèm ki egziste nan kontwòl ravinn ak nan jaden legim yo. Nan rejyon Nòdwès-la ewozyon si tèlman finn ravaje anpil ravinn, pou anpeche yo vinn pi mal se teknik tankou gabyon oubyen beton ki ta valab.

Efò Pwojè PLUS ap fè t-ap gen plis siksè si yo ta kontwole ewozyon-an depi kote li kòmanse. Fòs dlo-a ta diminye depi nan tèt mòn yo, sou mòn yo ak nan ravinn ki fèk fòme yo ki poko twò fon. Mi sèk nan ravinn yo ta dwe ranfòse ak wòch dèyè baraj ki fèt ak bwa ak plant yo, e mòn yo ta dwe pwoteje ak kòdon wòch.

Diminye fòs dlo-a se premye pa nan kontwole pwoblèm ewozyon e li ta dwe fèt depi nan tèt mòn yo. Sa ta mande pou Pwojè-a travay sou plis tè pase travay kontwole fòs dlo nan ravinn sèlman, men teknikman li mwen difisil. Nenpòt ki teknik ak sistèm ki diminye kantite ak konsantrasyon dlo k-ap desann soti nan mòn yo ap diminye posiblite pou genyen ewozyon paske fòs dlo-a diminye. Bon teknik konsèvasyon yo ap pote avantaj dirèk pou patisipan yo paske bon tè ak plis dlo ap rete nan jaden yo. Rejyon-an ak peyi-a ap benefisye tou paske ravinn ap sispann laji, ap genyen plis dlo anba tè, ap genyen mwens sediman ki desann nan bafon yo.

Li trè enpòtan pou fè bon jan antretyen sistèm pou ranmase dlo lapli yo, menmjan li enpòtan pou byen planifye ak konstwi yo. Fòk tè basen yo byen foule pou bouche tout twou pou dlo-a pa rantre nan tè. Vitès dlo-a ap rantre nan tè (enfiltrasyon) ka diminye ak ajil, sann, oubyen fimye melanje ak tè nan fon basen-an avan li foule. Enspeksyon ak entretyen te dwe fèt chak fwa yon gwo lapli finn tonbe. Men ki sa ki ta dwe fèt nan entretyen-an: netwaye basen-an pou retire sediman yo, repare kote dlo-a andomaje, foule tè-a kote dlo-a ap rantre nan tè.

Men sistèm ak teknik ki rekòmande pou kounye-a ak pi devan pou ede rezoud pwoblèm dlo pou jaden legim (BIG) ak lòt aktivite Pwojè-a:

a. Sistèm basen pou ranmase dlo lapli pou aroze jaden legim (BIG) ki pou pliziè moun ak sistèm ranmase dlo sou dal kay pou aroze jaden legim ki pou yon sèl fanmi. Dlo ki ranmase sou dal kay yo kapab sèvi san pwoblèm pou bezwen moun nan kay-la. Chema estrikti sa yo prezante nan anèks dokiman sa-a. Diskisyon te fèt ak pèsonèl rejyon yo pou planifye estrikti sa yo.

b. Seminè fòmasyon sou ti sistèm irigasyon ak pou moun yo konnen ki lè pou aroze, ta dwe fèt nan sant fòmasyon rejyon yo ak moun ki genyen jaden legim (BIG) yo.

c. Konstwi kòdon wòch ak ranp vivan nan ravinn ki pa twò gwo

ak mi sèk (sèy) nan pi gwo ravinn yo. Detay estrikti sa yo bay nan figi 1 ak 2 nan dokiman-an. Konsiltan-an te prezante bay pèsonèl biwo rejyon yo jan li panse estrikti sa yo ta dwe fèt.

INTRODUCTION

The objective of this consulting work was to develop recommendations for water harvesting systems development in the Northwest Region of Haiti for the BIG project and for livestock watering. The consultant also observed the currently used conservation measures from engineering viewpoints such as structure, strength, design and installation.

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h. A large scale hill-side runoff catchment system (approximately 30 m by 30 m) in Passe Catabois.

Itinerary for field trip

The consultant was accompanied by Yves Regis (a CARE regional manager who served as interpreter) and Yves Jean (a CARE driver).

March 10 Arrived Petionville, Haiti
March 11 Meeting with CARE, SECID, and USAID

Sites visited:

March 12 & 13	Bombardopolis (Patrick Conde and Gustin Judicael).
March 14 & 15	Barbe Panyol (Jean Claude and Gerry Delpin).
March 16 & 17	Passe Catabois (Joubert and David Herbe), Mr. Joubert joined the return trip to Gonaive. The trip was completed around 8:00pm at Petionville.
March 18	Meeting with CARE and SECID.
March 21	Meeting with USAID for debriefing.
March 22	Visited the Southeast Region (Marigot: Beri) for observation of conservation practices under high rainfall and steep slope conditions.
March 23	Returned to Auburn.

OBSERVATIONS AND RECOMMENDATIONS

A. Irrigation of Biointensive Gardens (BIGs)

The BIG project would be more successful if one or more irrigation water sources for each project site were easily accessible. In order to produce good quality marketable vegetables, irrigation would be necessary year round when adequate amount of rainfall (minimum of 25 mm/wk during cool and cloudy period and 35 mm/wk during warm and dry period) does not occur with adequate frequency (the required amount at intervals of 1-2 weeks). The amount and frequency of rainfall required are mainly determined by types of soil and crop.

When soil moisture is not enough so that plants can not extract adequate amount of moisture the plants start to suffer drought stress. If soil moisture is excessively low and continues long then the plants may not grow well, start to wilt, and eventually die. Plants transpire moisture to supply nutrients to grow as well as to prevent excessive increase in temperature. It may be observed that maize rolls its leaves to minimize transpiration loss of moisture on a hot afternoon. This may or may not indicate lack of moisture in the soil. It would be more likely that the plant needs more moisture to transpire than the soil can supply even though adequate moisture exists in the soil. But if this phenomenon continues for several days this may indicate lack of moisture in the soil which should be irrigated.

The source of irrigation water should be located close to BIG sites to minimize irrigation time. A BIG site at Bombardopolis was visited where the BIG participants transported water from a spring where it takes 20 - 30 minutes for a round trip to collect and deliver. Actual irrigation with a spray bucket (10-liter size) was done by another participant for a demonstration. Most of the BIG participants seemed to have a misconception that a vegetable garden needs to be irrigated twice a day, in the morning and in the afternoon. There is nothing wrong with irrigating with such frequency as long as they irrigate to meet the water needs of the plants. However, this frequent irrigation activity demands time which could be better utilized for other important garden activities such as pest control and garden maintenance.

A vegetable garden may be irrigated two or three times per week, at the most, to supply the required amount of water as mentioned above (25 - 35 mm per week) depending on the age of

plants and the weather. With the tool (10-liter spray bucket) currently used in the area, this can be done by irrigating 10 liters to 1.0 m^2 area twice a day (some farmers prefer this practice) every other day assuming 50% irrigation efficiency (assuming 50% of the water runs off the garden). This practice will deliver 2 cm of water every other day to the garden, resulting in a total of 3.5 cm added to the soil per week considering the 50% efficiency. Or the same result may be obtained with watering once every day with 10 liters on the same area. In the case of young plants (up to 1 month old) the irrigation may be done the same way but on a 2 m^2 area. This will deliver a total of 3.5 cm of water per week or 1.75 cm water added to the soil for plant use. Since young plants have shallower roots than mature plants and occupy a smaller area the efficiency may be improved through more precise irrigation by avoiding non-plant areas and runoff losses (See Table 1).

Irrigation efficiency would be improved by adjusting watering speed depending on the soil type. Watering speed should be slower for a clay soil (as found in Barbe Panyol) than a sandy soil (as found in Bombardopolis) to irrigate the same size area. The speed may be reduced by the person doing the watering as he/she sees runoff loss over the garden area. This will result in less runoff losses from a clay soil. Faster infiltration on a sandy soil will permit reduction of irrigation time with faster water application. However, sandy soil holds less water than clay soil.

A soil sample from Barbe Panyol was tested with a percolation can (see Appendix I) and its field capacity (FC) was found 35% by volume. By the same method it was found that a Bombardopolis soil had 25% field capacity by volume. In this test the soil samples were assumed dry as no rainfall or irrigation occurred more than a week before the sampling. Due to the soil property of strongly binding water only a portion of FC is available for plant uses. This portion is called water-holding capacity and approximately 50-60% of FC. Because of the different water holding capacity (higher for clay soil and lower for sandy soil) and infiltration rate (lower for clay soil and higher for sandy soil), one-time irrigation amount and irrigation frequency should be adjusted; i.e. less water, faster application, and more frequent irrigation for a sandy soil and more water, slower application, and less frequent irrigation for a clay soil. The BIG participants should be trained in techniques to achieve an efficient irrigation to conserve water and labor. Table below provides water-holding capacity (WHC) for representative soils. For other soils or better information the

method described in Appendix I may be used.

Soil type	WHC, mm water/cm soil
Sandy	1.0
Silty	1.5
Clay	2.0

A precious water source for irrigation is currently being wasted in the region. The consultant was told that most BIG participants did not use household waste water for garden irrigation as they believe that the water is bad for vegetables. This may or may not be true depending on the content of the waste water. More likely most household waste water contains plant nutrients which are good fertilizer sources. In many cases waste water from household may be used for vegetable irrigation unless the water is high in salinity due to excessive uses of soap. Most industrial waste water, of course, should be avoided for vegetable irrigation as it may contain toxic materials to crop and human.

B. Water Harvesting Techniques

Any water harvesting systems (either from field or roof) would have potential benefits: 1) providing water for irrigation, livestock, and other beneficial uses; 2) reducing runoff in ravines; and 3) recharging aquifers in the region. The first benefit would provide direct incentives to the BIG participants and others who build water harvesting systems and the other two would provide the region and the country with a long term benefit.

The climate and landscape of the region seem to be adequate for water harvesting systems and demand for such water is high in the area. It was observed that villagers are interested in the BIG project, which requires good source of irrigation water for better crop production as well as livestock watering. During the consulting visit to the Northwest Region various water harvesting systems were observed. Some of them were completed and partially in use and others were under construction. It was found that some of the completed systems were not functioning as designed or not in use at all due to various problems: inadequate design and construction and lack of maintenance to list some. Water harvesting systems under construction in the region include MARNDR and a French organization funded roof catchment projects and a road-side catchment project funded by a German agency. If the PLUS project is not interested in funding such water harvesting systems development, it would be beneficial to find a way to coordinate the BIG project sites with one or more of currently functioning water

catchment systems. It is also important to identify and renovate abandoned or not-in-use water harvesting systems for the same purpose.

In general, it is feasible to harvest water from roofs, roadsides, and hill slopes in the three regions visited during the consultancy. A roof catchment system is proposed for the Northwest Region and is shown in Figure 3. It is similar to the existing systems in the region but with a few modifications. In Bombardopolis and Passe Catabois regions, large scale community-based water harvesting systems (over 1,000 m^3 water holding capacity) could be developed should pond sites be available. The pond should be strategically located so that the catchment area would be the area where runoff flows toward the pond through roads and farm fields. If needed contour terraces may be used to direct runoff water from catchment fields to the pond (See Appendix III).

One of the problems mentioned by the people who had installed dug-out ponds was seepage loss of the stored water. Another loss of the stored water is by evaporation which is difficult to control but often negligible compared to the problem caused by seepage. The total potential evaporation loss in the area was reported to be up to 1500 mm a year, the full capacity of a 1.5 m deep pond. Evaporation loss is only a portion of the total supply capacity of the pond, since a water storage pond is often designed to fill several times a year by providing the catchment size many times larger than the pond size.

Seepage rates vary from less than 1.0 mm to several mm per hour depending on the conditions of the pond bottom and walls. Of course seepage can be controlled if a pond is lined with impervious materials: plastic sheets, concrete, or clay. The calcareous nature of the limestone formation in the region permits excessively high seepage losses. Seepage may be prevented with lining as mentioned above but these materials are expensive to use for large ponds and some have short life due to deterioration or cracking. An appropriate technique which is inexpensive but labor intensive is to compact the pond bottom soil.

Proper compaction of pond soil can effectively seal pore spaces which results in reduced seepage losses. Seepage rates are further reduced with clay, ash, or animal manure which is spread on the pond bottom and mixed with the soil before compaction. There are no references found presenting mixing ratio of such materials with soil but it is my recommendation to have approximately 2.5 cm thick cover of a mixed material with 1 : 5 to 1 : 10 mixing ratio. Of course, a thicker layer of such mixed material would further reduce seepage losses even more.

Proper soil compaction of a dug-out pond may be achieved by the following technique with no or minimum monetary outlay:

1. Fill the pond with runoff water after completion. This would add some fine materials carried by the runoff to the pond.

2. When the pond water is completely lost by seepage wait a day or two before compaction to obtain a proper soil moisture content in the pond soil for proper compaction. Compaction of soil may not be well achieved if the soil is too dry or too wet. Some materials such as clay, kitchen ash, or animal manure may be spread over the pond bottom and walls and mixed with the soil before compaction.

3. Build a soil compactor with a 1.5 ft by 1 ft by 1 ft thick (approximately 200 lbs) locally available flat stone. Hang the compactor with a rope from two handles in a cross arrangement so that two men can lift and drop the compactor. A similar tool may be built with a palm tree trunk. A minimum of five droppings on the same spot would be needed to achieve a good compaction. This compactor may be used to compact the bunds around the pond which are built with the excavated soil.

4. Build a 1 ft by 1 ft by 0.5 ft thick compactor (approximately 30 lbs) for side wall compaction. Attach a stake type handle so that one man can hit the pond walls to compact.

If seepage still remains excessive (when water level in the pond drops more than 5 to 10 cm a day) it might be necessary to compact again or line with plastic or other impervious materials. The pond area should be fenced to reduce the danger of drowning of children or livestock. Hedgerows of leucaena or other trees/shrubs are appropriate for this purpose.

Good maintenance of water harvesting systems is of utmost-importance as well as design and construction of the systems. Checking of the systems and necessary maintenance should be done after major storm events. Maintenance should include; cleaning of sediments from sediment trap and pond, repairing of washed areas, and additional compaction should seepage increased.

C. Soil/Water Conservation Techniques

In my observation, hedgerows were found the best among the PLUS conservation measures. The technique was successfully controlling erosion on the hill sides. It also caused runoff to slow down and to spread out over a wider area. This provides more

time for the water to infiltrate not only to provide more soil moisture but to recharge the aquifer, the important source of spring water in the region. The technique effectively traps sediments to promote soil conservation and reduces runoff in the gullies below. Rock walls or hedgerows installed across shallow ravines may be modified to direct the runoff to spread out over a wider area on the surrounding hill slopes (Figure 1).

A conservation measure used in the area was the vegetative gully plugs installed across deep ravines. One of the problems of this system would be the potential wash-out of the plugs by rainfall events which may carry destructive heavy runoff into the gully. A site in Bombardopolis was observed where gully plugs were completely washed out by a large storm last December. This not only destroyed the gully plugs but damaged the gully itself.

In the consultant's opinion the vegetative check dams are not structurally stable nor strong enough to sustain such heavy sediments trapped behind them especially during large runoff events. Vegetative plugs installed in deep ravines should be reinforced with rocks and rock-wall terraces should be installed on both sides of ravines to control runoff from the hill sides of the ravines.

Vegetative plugs seem to have a relatively short life due to occurrence of destructive high intensity rainfall events in the area. It is recommended that plugs be installed step by step with a height of no more than 30 cm at one time with a 30cm top width and 1 : 4 (4 vertical over 1 horizontal distance) outside wall slope (Figure 2). When the area behind the plug is filled with sediments another plug is installed at a minimum of 15 cm behind the lower plug and so on until the last plug is installed. This will develop the structure in the shape of a pyramid in which the lower plug supports the plug above (Figure 2). The maximum height of the structure should be determined by the size of gully and potential maximum runoff. However, it is recommended that plug height be limited to no more than 1.0 m and that the number of plugs along the gully be increased as needed. In this way the potential loss of plugs in a gully would be minimized.

D. Aquaculture potential with water harvesting systems

In addition to the benefits of water harvesting systems listed above, the stored water could be effectively used to raise fish if the ponds can retain water for an adequate length of time. Fish are a good protein source for domestic consumption as well as a marketable commodity in Haiti where fish used to be important part of the daily diet. Also some fish species can effectively control mosquito larva in open ponds. One of the most common fish raised in tropical climates is tilapia. This fish grows fast (4 months to

a market size from fingerling) and no or minimum commercial feeds are needed. Tilapia feeds on algae in pond water where animal manure and other types of organic nutrients are used to fertilize the pond.

As water harvesting systems become available, this type of high income and protein production program should be considered as it would provide great benefits and opportunities for the BIG participants. Even with the 600 - 900 mm per year rainfall the rainfall pattern in the region could provide enough water in ponds for the needed length of growing period to produce fish from April through November. However, raising fish requires more than just water and feed. Supply of fingerlings and necessary knowledge and information for the local conditions should be provided to the participants.

There are currently two aquaculture program graduates in Haiti who studied at Auburn University. Auburn University is well known internationally for its aquaculture research.

E. Water Carrying Tools

Finally even though this is not a part of this consulting work I am compelled to suggest the following. It is strongly suggested that BIG project search for a better way for the participants and others to carry water than the way they currently do. They transport water in a 8-gallon plastic bucket carried on the head or by hand. This is an inefficient and difficult way to carry water. There are better ways to carry the buckets: on the back or on the shoulder such as used in the orient and many other countries. One is a leverage type arrangement by which two buckets are balanced on the shoulder and the other is a backpack type in which one bucket hangs on each side. This suggestion or any other better means of carrying water should be introduced to the villagers and the BIG participants to relieve the burden, especially on women and children.

F. Suggested future activities to be included in the PLUS project:

The following activities are suggested based on various discussions with the field personnel and the project management officials of USAID, CARE, and SECID/AUBURN.

1. Erosion prediction - Several computer models have been updated after the Universal Soil Loss Erosion (USLE). These models are based on various techniques for predicting runoff, erosion and associated non-point source pollution from crop fields and multiple land-use watersheds. These models include RUSLE, WEPP, GLEAMS, AGNPS, ANSWERS to list some. These models may be utilized to evaluate the conservation measures used in the project. However, it

requires field data to verify the model application to the area because of the steep and highly eroded field conditions. The consultant has been involved in using these models for research and teaching purposes.

2. Rainfall analysis of Northwest Region - It is possible to analyze the existing rainfall data recorded at various sites of the region to determine the rainfall trend: intensity, duration, recurrence pattern, and seasonal variation.

3. Soil erosion field study - The PLUS agroforestry experimental site at Freres could be equipped with a runoff and sediment measuring device to study the impact of current soil conservation practices. The data from this study would be valuable to validate erosion prediction models listed in 1) above for severely eroded steep slope conditions.

4. Development of large scale community based water harvesting systems - Water harvesting systems would be beneficial by reducing runoff from high plateaus to the ravines as well as providing needed water for irrigation and livestock. Such project would require preliminary study before development and implementation. The consultant has expertise to conduct such project development in arid and semi-arid regions.

5. Training workshops for the field staff of the PLUS project on soil and water conservation, water management, water harvesting, and irrigation.

6. Cooperation and information exchange with Haitian researchers for the suggested activities above. This would provide opportunities for the Haitian researchers to interact with outsiders on these important natural resources conservation activities.

The consultant is strongly interested in these activities through technical assistance, consultation, or direct research participation should funding be available.

Table 1. Irrigation scheduling for the BIG garden project in the Northwest Region of Haiti.

Assumptions:

1) 50% irrigation application efficiency - one half of the water applied to the soil surface would runoff of the field.

2) 3.5 cm per week water required by the crop. This is based on the 1500 mm evapotranspiration rate reported for the area.

Irrigation practices:

1) A 10-liter spray bucket.

For a mature crop - after one month old.

a) An area of 1 m^2 will be watered with a 10-liter water bucket. Each bucket will deliver 1.0 cm of water to the 1 m^2 area. Assuming 50% efficiency the amount of water applied to the soil surface should be 7 cm, which will add 3.5 cm of water to the soil for plant use.

b) This can be achieved by irrigating the 1.0 m^2 area with a 10-liter bucket twice a day every other day (early morning and late afternoon) or once a day everyday (early morning or later afternoon).

c) To irrigate 100 m^2 area one hundred buckets of the 10-liter is needed per irrigation.

For a young crop - before one month old.

a) The same practice over 2 m^2 area. Young plants have shallow roots and are smaller in area to irrigate so that more efficient irrigation can be achieved by pin-pointing where water is applied.

2) The frequency may be reduced if the irrigator feels that less water runs off the field during irrigation, i.e. more efficient irrigation. The slower water is applied the more water infiltrates resulting in less runoff loss. However, it will require more time to irrigate. The irrigator needs to decide the balance between the time to deliver water and to irrigate.

3) Suggestion: A training workshop to the field personnel on irrigation technique and other topics relative to water and soil conservation for the conditions in Haiti.

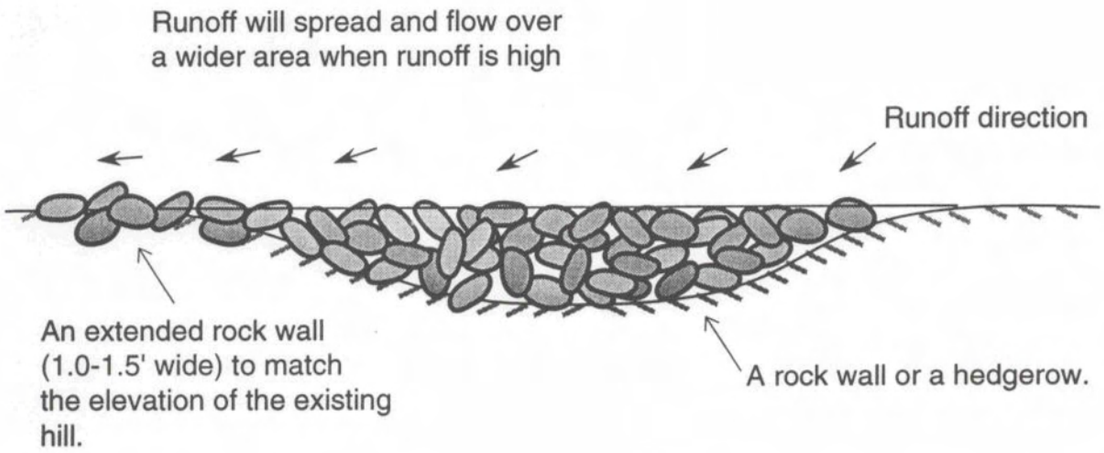


Fig. 1. An extended rockwall or hedgerow installed across a shallow ravine on hill slopes to spread runoff water.

This structure and the structure in Fig. 2 should be provided with an overflow spillway at the center to prevent water flowing around the sides which would cause erosion problems. The spillway may be 0.5 ft. deep (lower than the structure top) and 2-3 feet wide depending on the structure size.

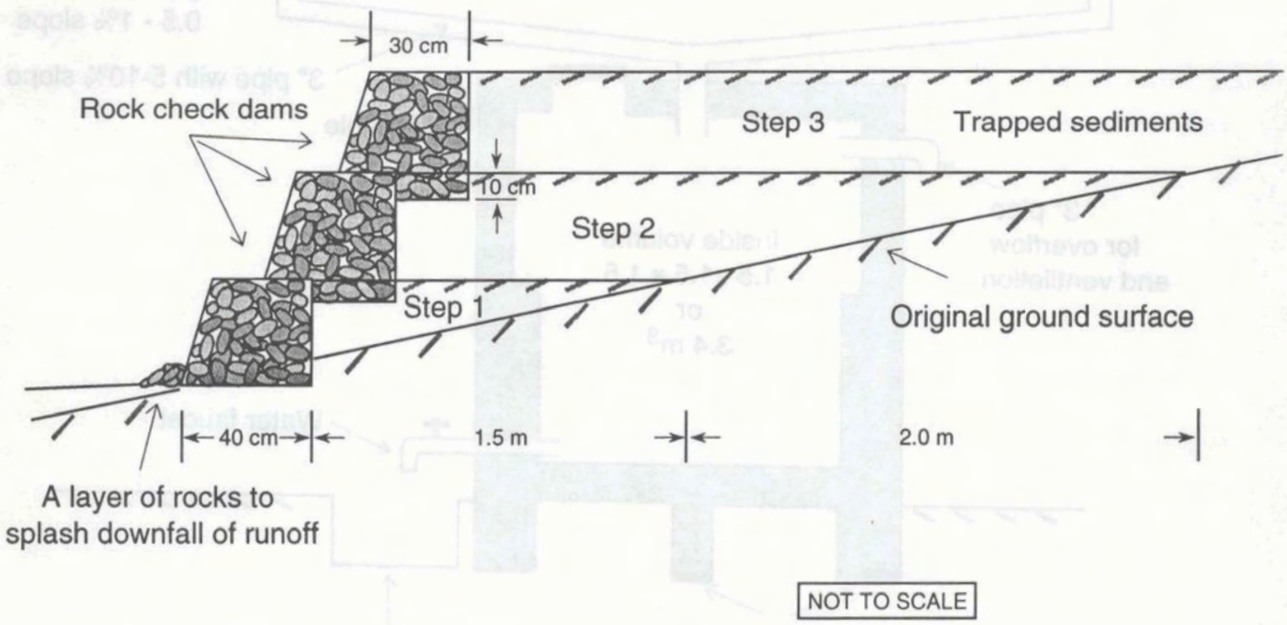


Fig. 2. A Gully plug design to improve sustainability.

This structure with 20% gully slope will create a 4.5 m long flat field filled with trapped sediments behind the structure. The height of each plug may be adjusted up to 40 cm high depending on gully slope and size.

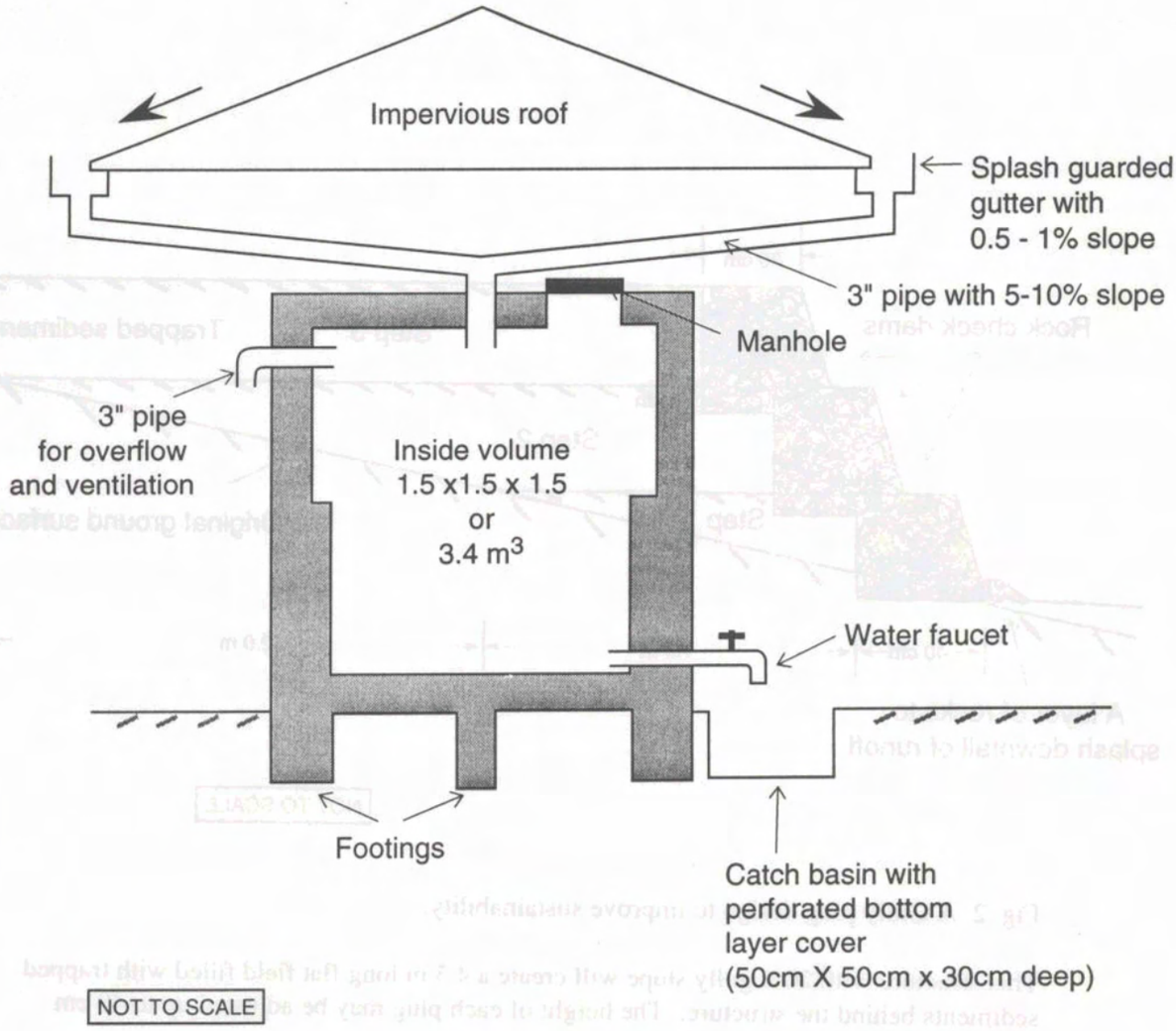


Fig. 3. A design of a roof runoff catchment for the Northwest Region of Haiti.

Numerical example of a tank design for a roof runoff catch shown in Figure 3:

1) Roof area with hard surface - 3 m by 10 m each on both sides of a roof.

2) Targeted rainfall - a total of 150 mm to fill a storage tank.

3) Assume 80% catchment efficiency with good gutter layout. Gutter should be laid with a slope so that overflow from the gutter during high intensity rainfall would be minimized.

Total volume of water to be harvested from a single storm of 150 mm.

80% x 3 m x 10 m x 0.15 = 3.6 m^3

Recommended size of a concrete brick or stone walled storage tank with a solid cover.

1.5 m x 1.5 m x 1.5 m deep = 3.4 m^3

The thickness of tank walls built with local bricks or stones should be studied to avoid possibility of collapse from internal water pressure and outside damage. The wall should be as thin as possible to minimize cost but as thick as necessary to avoid collapse. Since most internal and outside pressures occur in the lower portion of a tank it is recommended to build a tank with two thicknesses as shown in Figure 3: two layers of good concrete brick or good stone on the lower half and one layer of them on the upper half. Structural strength may need to be confirmed through a test. The maximum pressure on the wall reaches 1125 kg at the 1.0 m from the top when the tank is full.

A catch basin at the user outlet should have a permeable bottom made of 2 - 3 layers of locally available plastic grain sacks to drain any accumulated water. Roof catchment systems observed in the region had such a basin which has impervious bottom. The basin holds water after use of the water and collects rainfall water. The accumulated water in the basin had become a mosquito breeding site.

Appendix I. A simple homemade tool to approximately determine field capacity (FC) of a soil.

Procedure: See Figure I-1 of this Appendix.

1) Collect a soil sample from a designated field where no rainfall or irrigation has occurred within a week or longer. This will provide a well dried soil sample for this test.

2) Add the soil sample in a tester described in Figure I-1 for 5 - 10 cm depth. Lightly tap the top of the soil with a flat bottom tool.

3) Add a known volume of water into the tester (350 cc cola bottles are readily available).

4) Set the tester on a catch container with free space between the container and bottom of the tester to provide free drain. Store the tester indoor and let the water drain overnight. Collect the drained water.

5) After a complete drain of the water measure the drained water. Determine the soil volume by measuring the soil depth and inside diameter of the tester.

6) Calculate field capacity (FC) of the soil as follows.

$V_s = d \times 0.75\ D^2$

V_s = soil volume, cm^3,
d = soil depth in the tester, cm
D = inside diameter of tester, cm.

$$FC = \frac{V_w - V_d}{V_s} \times 100$$

FC = water holding capacity, % by volume,
V_w = volume of water added to the tester, cm^3,
V_d = volume of water drained from the tester, cm^3,

Field capacity in percent provides information that the tested soil can hold water up to the percentage portion of the root depth. However, only a portion of FC is available for plant use. This portion is called water-holding capacity (WHC) and is approximately 50-60% of FC.

For an example:

Corn has a root depth of 35 cm which will be irrigated. Assume a soil which has a FC of 35%. Then the soil in the root area can hold 0.35 x 0.6 x 35 cm or approximately 7.0 cm of water for plant use. When this water is filled in the soil the soil can supply water up to 2 weeks assuming 3.5 cm per week water use by the crop. If irrigation efficiency of 50% is considered then the soil should be irrigated with 14 cm of water every two weeks. However, often it is too late to wait until all the water in the soil is used up because the low moisture content at the end of this period may cause a drought stress. Instead, irrigation should be done when one-half of the WHC is consumed. Therefore, this field should be irrigated every week with 7.0 cm of water per irrigation.

Considering the field conditions in the Northwest Region the 7.0 cm irrigation amount may be applied every week as the BIG participants prefer frequent irrigation. Daily irrigation of 1 cm (10 liters per 1 m^2) or 2 cm (20 liters per 1 m^2) every other day will meet the irrigation demand. This is similar to the irrigation scheduling presented in Table 1.

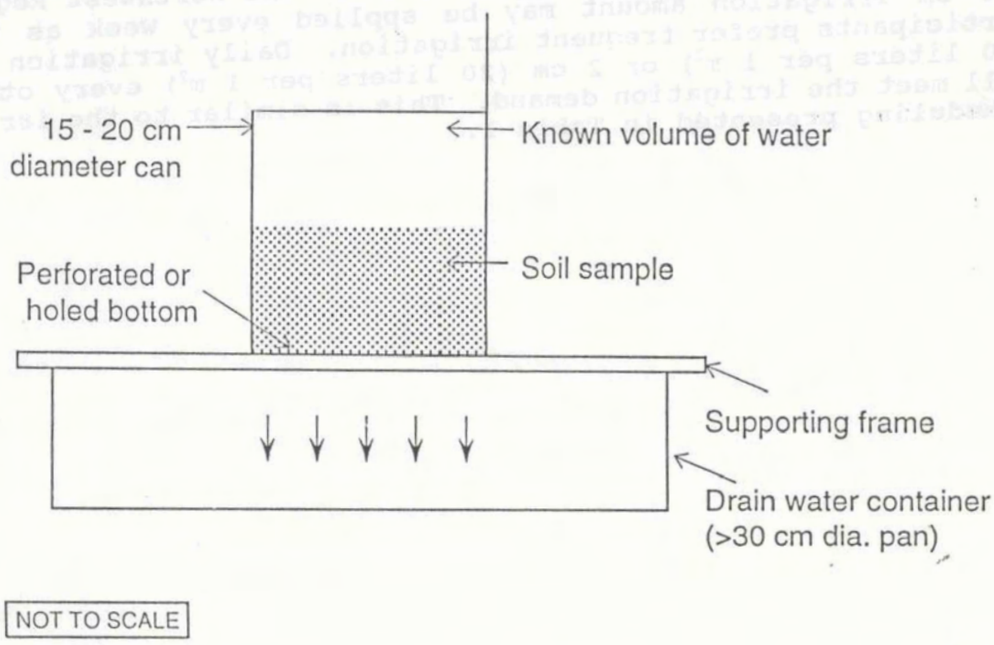


Fig. I-1. Schematic of a homade tool to approximately determine field capacity of soil.

Appendix II. Schematic of a dug-out pond.

Criteria used in this design based on information collected during the field trip. See Figure II-1 at the end of this Appendix.

1) Runoff from a storm of 25 mm per filling cycle. This means that runoff from each 25 mm rainfall would fill the designed storage ponds from empty. Therefore, any storm higher than this or if rain falls when pond is not empty would cause overflow.

2) Runoff potential per rainfall of 25 mm

a. 10% from mild slope (< 5% slope)
b. 25% from medium slope (5 - 15% slope)
c. 40% from steep slope (15 - 30%)
d. Pond construction should not be recommended for slopes over 40%.

3) A total of 70 mm water per irrigation is needed to add 35 mm into root zone. Water loss due to seepage and evaporation is assumed 25% of the full pond water. Then to irrigate 100 m^2 the storage capacity per irrigation needed is:

$$100\ m^2 \times 0.070\ m / 0.75 = 10\ m^3$$

4) Three sizes of catchment area will be calculated to collect 5 m^3 water considering the runoff potential from different slopes.

a. < 5% slope surface with contour terraces.

$$10\ m^3 / (0.025 \times 0.1) = 4{,}000\ m^2$$

b. 5 - 15 % slope surface with no contour terraces. Catchment area may be smaller should contour terraces or other means is provided to direct runoff.

$$10\ m^3 / (0.025 \times .25) = 1{,}600\ m^2$$

c. 15 - 30 % slope surface with no contour terraces. Catchment area may be smaller should contour terraces or other means is provided to direct runoff.

$$10\ m^3 / (0.025 \times 0.4) = 1{,}000\ m^2$$

A hill side water harvesting system will be composed of three components: hedgerow to trap rock, sediment trap basin, and water storage basin. An open channel will connect the sediment trap and

the storage basin. At the lower end of the storage basin an overflow spillway will be installed (See Figure II-1).

A pond depth of 1.5 m will be used for all design considering safety. However, with secure fencing around a pond the pond may be built deeper than 1.5 m. A square is the most efficient shape of pond to build in terms of the ratio of earth movement and storage capacity compared to other rectangular shape. In fact a circle provides the most storage capacity for the same amount of digging. However, a different dimension of rectangular shape will be used on hill slopes to minimize height of bunds on the lower side as shown in figures.

See Figure II-1 below for dimensions for a dugout pond design. Dimensions for different surface slopes are:

(All units in meters)

a) 0% slope

a = 3 to 5	b = 1	c = 1 to 2	d = 0.4	e = 2.5
f = 2 to 3	g = 1.5	h = 1 to 2	i = 2.5	j = 3
k = 1.2	l = 3.2	m = 0.3	n = 0.3	

b) 15% slope

a = 3 to 5	b = 1	c = 1 to 2	d = 0.4	e = 2
f = 2 to 3	g = 1.5	h = 1 to 2	i = 3	j = 3.5
k = 1.2	l = 2.6	m = 0.4	n = 0.3	

c) 30% slope

a = 3 to 5	b = 1	c = 1 to 2	d = 0.4	e = 2
f = 2 to 3	g = 1.5	h = 1 to 2	i = 3.5	j = 4
k = 1.2	l = 2.6	m = 0.4	n = 0.3	

To facilitate a pond to irrigate more than once between fillings and the pond surface and catchment sizes should be multiplied by the desired number of irrigation.

Side slopes of a pond should be 1 horizontal to 4 vertical distance. This will have approximately 75 degree slope on the pond side walls. If desired a fence may be used around the storage pond and the sediment trap to keep livestock and children for safety and maintenance. At Bombardopolis site, where a multiple family BIG project is located, hedgerows may be used along both sides of the hill walkway to reduce sediments moving into the catchment area.

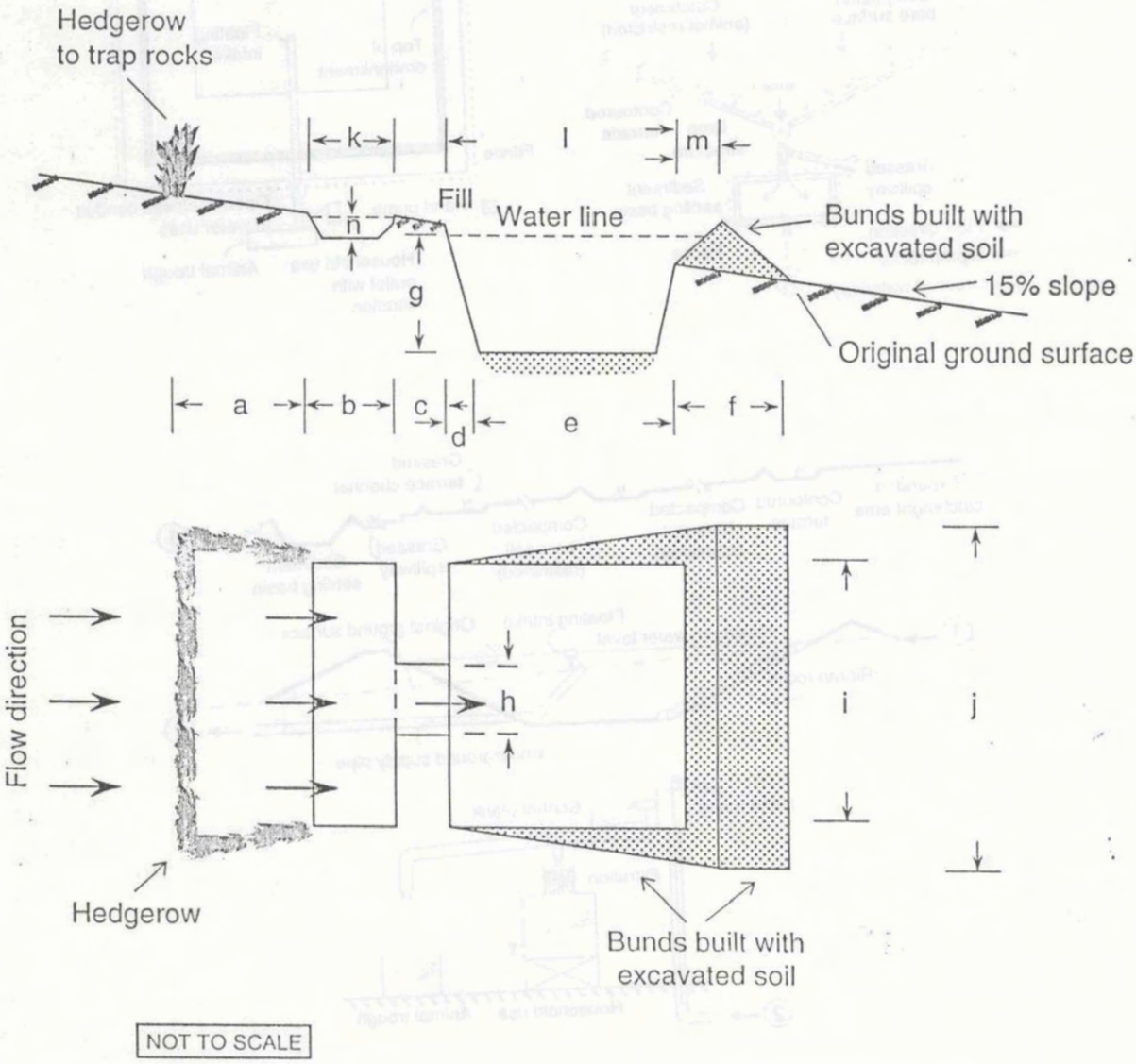
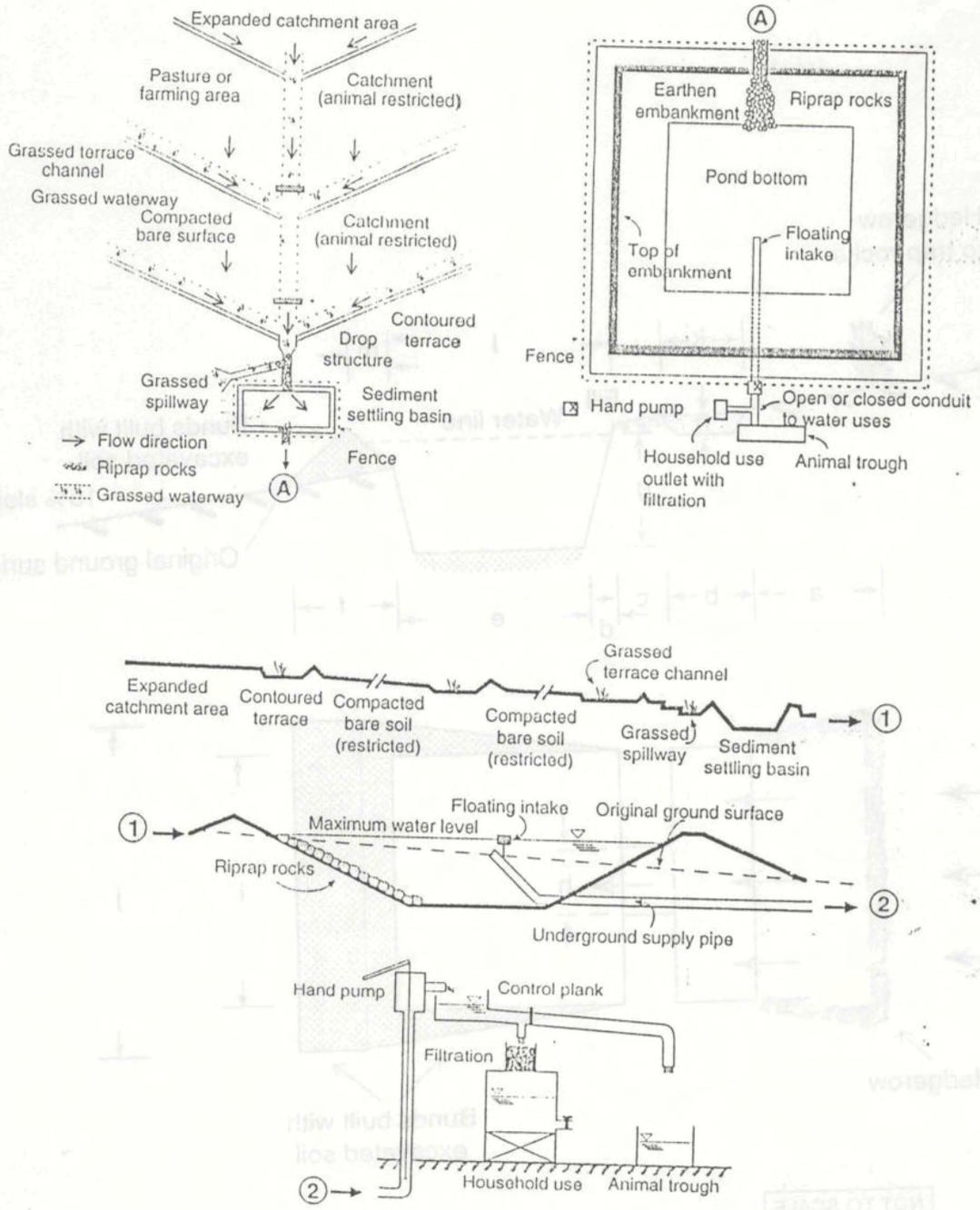


Fig. II-1. Schematic of a dug-out pond design for a field water harvesting system.



Appendix III. Schematic of a conceptual field water harvesting system.