Small-Scale Water Management in Farming Systems in the Brazilian Arid Zones

Everaldo Rocha Porto and Aderaldo de Souza Silva
Center for Agricultural Research in the Semi-Arid Tropics
Petrolina, Pernambuco, Brazil

ABSTRACT

The semiarid tropics in Northeast Brazil occupy an area of 1,149,000 square kilometers and contain 24 million inhabitants. Most of the people are dependent on subsistence farming characterized by small land holdings, limited financial resources and productivity that is both unstable and low. Natural resources are limiting factors. Rainfall is highly variable and poor soils predominate.

The Center for Agricultural Research in the Semi-Arid Tropics was established by the Government of Brazil to seek ways to change the low quality of life endured by the residents of the Northeast Region. A comprehensive program to promote and improve small-scale water management in the region is underway there. Components under study include runoff inducement, microcatchment water harvesting, recession farming, life-saving irrigation, pot (pitcher) irrigation and cisterns for drinking water. Significant technical achievements have resulted to date. The need to improve technology transfer has been recognized.

INTRODUCTION

A large portion of the world's population today lives and depends on agricultural production in arid or semiarid environments. Subsistence agriculture based on rainfall, small farms, limited capital resources, limited water storage, dependence on animal or human labor and lack of credit facilities are common characteristics of the productive process in those areas. Thus, unstable food production and low productivity are the results.

From the viewpoint of natural resources, arid and semiarid zones have shallow soils low in fertility, infiltration capacity, moisture-holding capacity and organic matter content. In addition, they also are subjected to intensive rainfall interspersed with droughts, high evapotranspiration rates and a great erosion hazard. For the majority of such areas, erratic rainfall is the only source of water, and no attempt has been made to conserve soil and water at the farm level, with the situation becoming worse every day. In recent years, government and donor spending on relief programs has been increased substantially.

Traditional farming systems in Northeast Brazil include crops and livestock. The cultivation pattern involves the practice of intercropping with annual crops as a way to reach equilibrium with the environment and the socioeconomic situation. However, the small farmers of the arid/semiarid zones have failed to satisfy even their minimum needs. Furthermore, other opportunities for farmers to generate family income are too limited.

In spite of frequent failures experienced by the farmers, they are willing to use improved technology. However, because of the limitations and characteristics involved in farming in arid and semiarid zones, the application of improved technologies has not had the expected impact.

The Agricultural Research Center for the Semi-Arid Tropics (CPATSA) was created by the Government of Brazil in 1975 with the objective of generating new technologies to improve the quality of life of the peasant farmers of the Brazilian semiarid tropics. During succeeding years, alternative solutions for known limitations were generated in the following research topics: small-scale water management, intercropping, forestry, soil fertility, grain conservation, fruticulture, mechanization, animal production and agroclimatology. All the generated alternatives have been developed based on single-component approaches. During the last few years, CPATSA has concentrated efforts to increase effective utilization of a systems approach in its research program.

The present paper offers a brief overview of CPATSA's approach to farming systems research for arid zones with emphasis on small-scale water management.

AGROECOLOGY OF THE BRAZILIAN SEMIARID TROPICS

Natural Resources

The region covers an area of 1,149,000 square kilometers and exhibits a pronounced time and space variability in rainfall distribution (1). In large portions of the states of Rio Grande do Norte, Paraiba, Pernambuco and Bahia, the rainfall is so little that they can be classed as very arid (2). Also, small portions of Piaui, Alagoas and Sergipe are similarly classified (Figure 1).

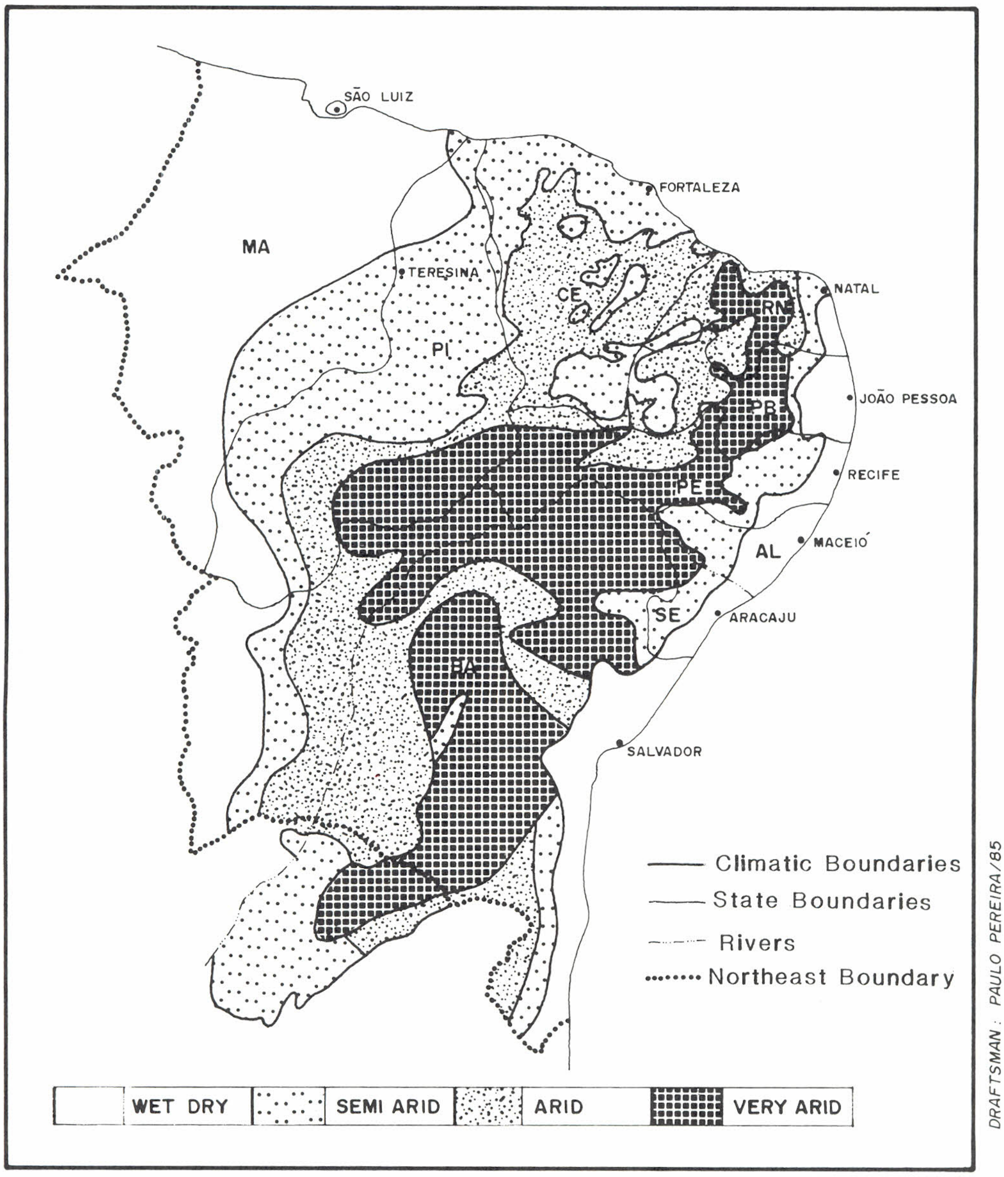

Figure 1. Climatic zoning for agricultural production in Northeast Brazil.

Rainfall amount within the year is not the only factor for determining the potential for drought. The evaporative demand is also extremely important in causing the disequilibrium for water availability. In general, the rainy season is from October to September. However, three distinct rainfall patterns can be identified in the region (Table 1). Solar radiation does not vary significantly from county to county, but does vary within the year (Figure 2). Because of that, potential for crop production varies from county to county with the level and distribution of annual precipitation (3). Examples of this can be seen in Table 2.

Table 1. Rainfall distribution in the semiarid tropics.

Location	Annual Mean	Percent of annual mean											
		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Casa Nova-BA	507	1	4	12	23	13	15	20	--	--	--	--	--
Irece-BA	573	0	1	20	21	18	11	17	--	--	--	--	--
Petrolina-PE	400	--	--	--	16	13	19	23	10	2	1	--	--
Jaicos-PI	669	--	--	--	17	22	25	12	3	0	0	--	--
M. Isidoro-AL	654	--	--	--	--	--	5	9	12	16	15	13	9
N.S. Gloria-SE	668	--	--	--	--	--	5	6	10	17	15	15	9

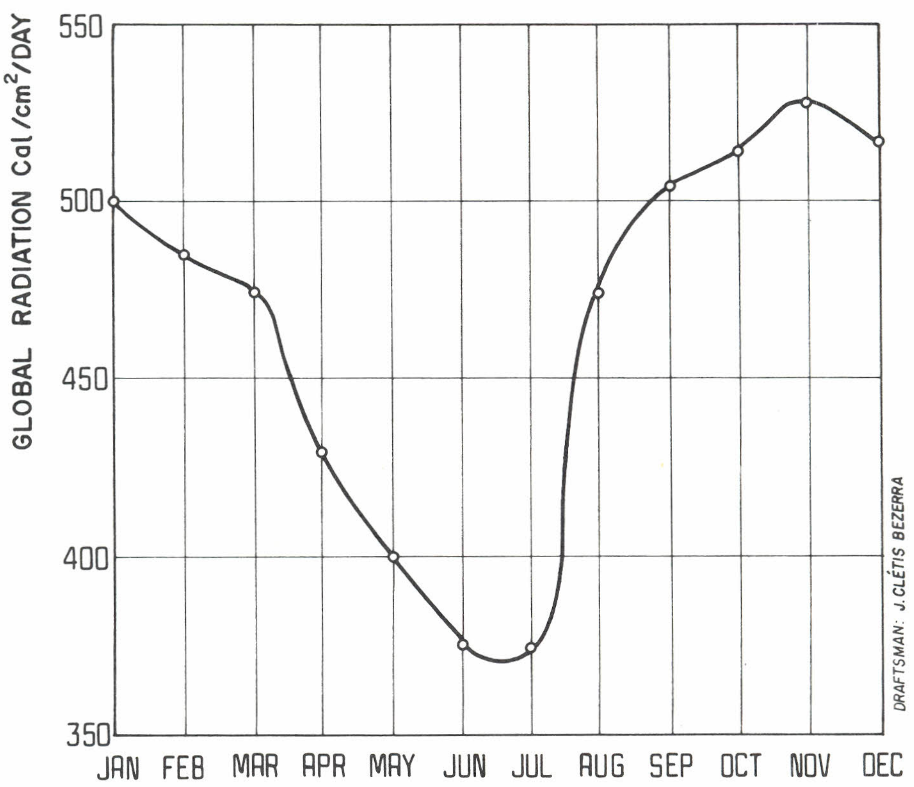

Figure 2. Monthly distribution of solar radiation in semiarid tropical Brazil.

Table 3. Typical planning elaborated with technical assistance and subsdized interest rate.

	U.S.$[a]
Construction of a small reservoir	1,092.00
Remodeling of the family's house	833.00
Construction of 3,000 meters of fence	1,360.00
Repairing of old fence	411.00
Planting 11 hectares of buffelgrass	2,412.00
Planting 6 hectares of cactus and cotton	450.00
Acquisition of one forage processing machine	607.00
Acquisition of two calves	715.00
Acquisition of two bullocks	500.00
Acquisition of one bull	387.00
Taxes and other fees	1,230.00
	9,907.00

[a]1 U.S.$ = 40.00 Cr$

Runoff Inducement

The study of this component had two phases. In the first one, the concept was to utilize the poorest land for producing runoff without any treatment. In the second phase, the concept was to utilize the various methods of runoff inducement including combinations of intensified grassed water-ways, strip clearing of *caatinga*, narrow-based channel terraces, salt treatment on cleared strips and complete clearing of *caatinga* with a grass cover (Figure 3).

Cisterns for Domestic Water

In the rural zone, drinking water is a great problem. In this area, the families utilize whatever water they find to supply their needs. Usually, they share the same water source with the animals. This aggravates even more their sanitary situation which is already unsatisfactory.

In the Brazilian semiarid tropics, cisterns are used as small tanks constructed with bricks for storing drinking water collected from roof tops. This kind of cistern, very common in the urban area of the region, is unusable in the rural area. The reasons are two: the catchment area in general is not large enough to produce the required amount of water, and the cost is too high for small farmers.

On that basis, CPATSA tried to develop a cistern more appropriate to rural conditions by using the soil itself as the catchment area, with plastic and chicken-wire mesh. With this approach the cost was reduced by 40 percent when compared with the original ones, for the same storage volume. Figure 4 presents some details of this kind of cistern.

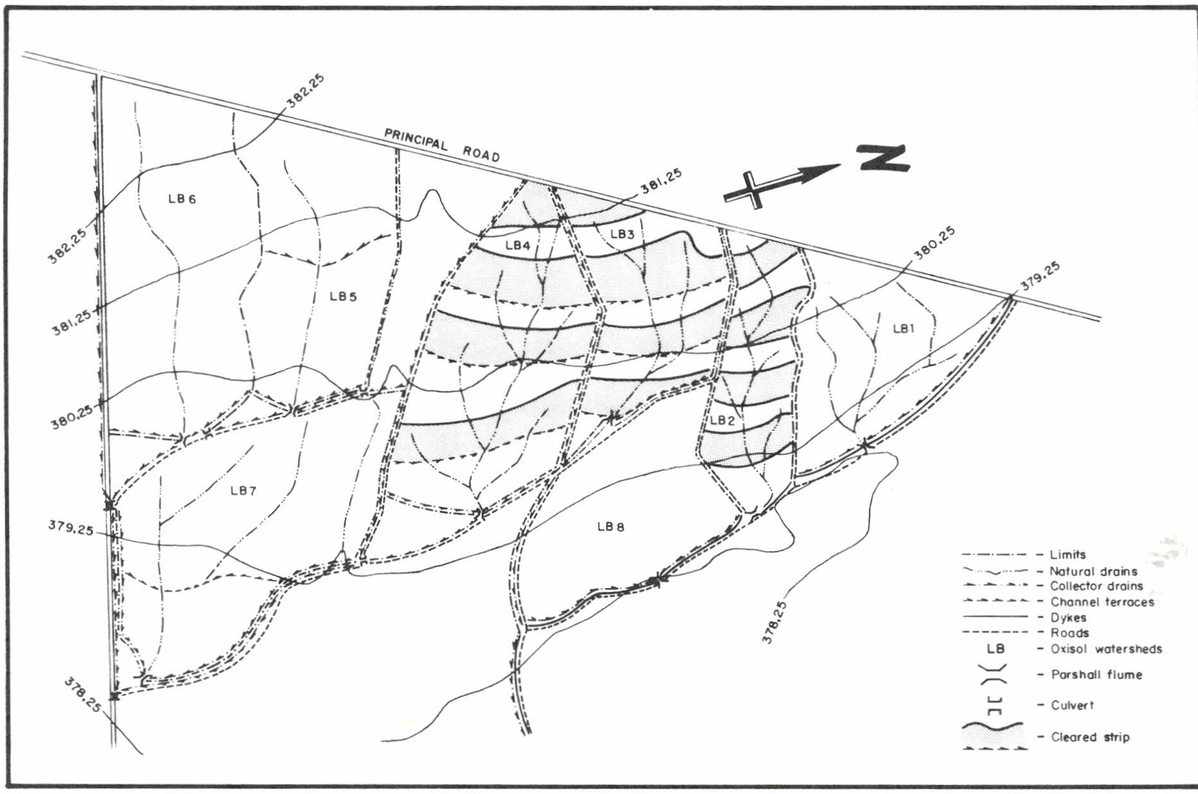

Figure 3. Demonstration site for runoff inducement through different soil and vegetation treatments (5).

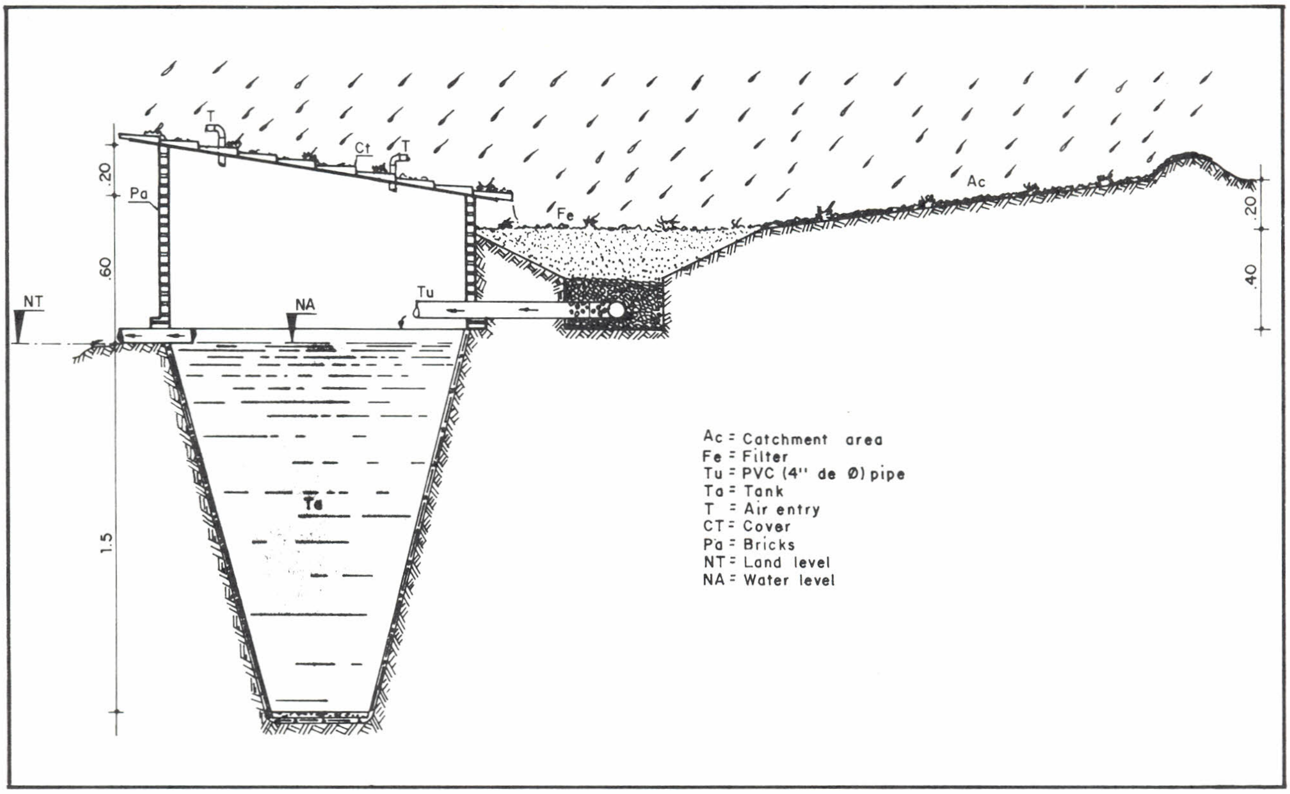

Figure 4. Schematic design for the cistern developed by CPATSA.

Small Reservoirs for Life-saving Irrigation

The collection and storage of portions of excess rainfall, and its later application as irrigation, can markedly reduce the chance of failure involved in rainfed agriculture. However, due to the scarcity of groundwater, runoff is considered the main source of water for the region. Moreover, the energy price in Brazil is so high that pumping cannot be considered an input for subsistence agriculture.

On the other hand, before runoff can occur precipitation must satisfy infiltration and surface retention demands. Runoff also is affected by the time of concentration. As the time of concentration decreases, the rate of runoff per unit of watershed tends to decrease.

Using these principles, CPATSA developed a system that can be utilized for irrigation by gravity. Figure 5 presents a schematic view of such a system.

The starting hypothesis for designing the system was that with 100 millimeters of extra water for each cropped hectare, the chance for harvesting a short-growing season crop can be increased to 80 percent in an area with 400 millimeters of annual rainfall. CPATSA has been working at the farmer level with this technique since 1979, and good yields have been harvested so far, even with annual rainfall as low as 250 millimeters.

Another assumption was that the minimum cropped area for the system must be 2 hectares, which seems to be reasonable. However, the correct minimum area can be identified by an optimization process.

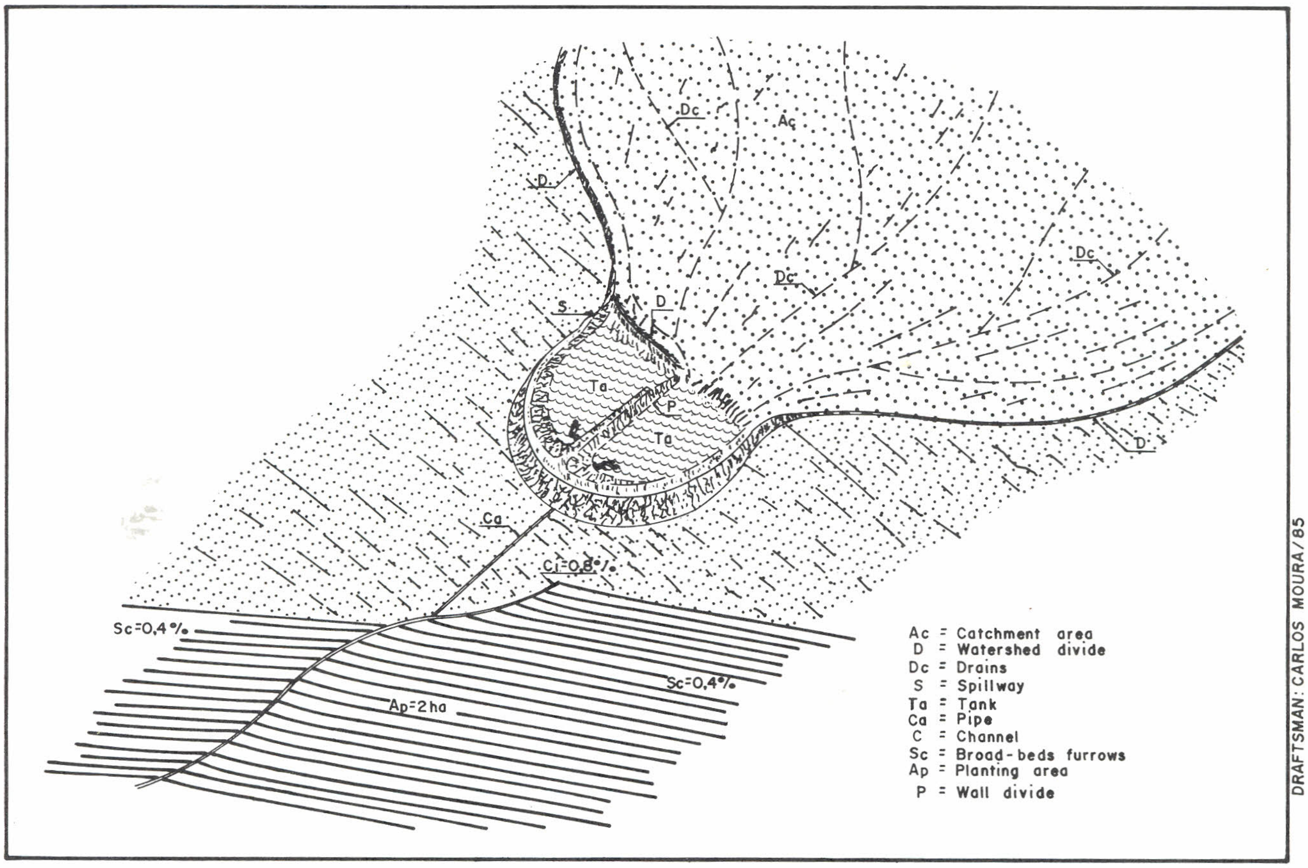

Figure 5. Schematic design for the system developed by CPATSA for life-saving irrigation.

Evaporation presents an undesirable effect on water stored on the surface. This effect becomes worse for counties in which the rainy season involves the months of November, December and January. As an example, in the hydrologic year of 1980-1981, the rainy season in Petrolina, PE, started in December with a storm of 100 millimeters of rain. Because it was a high intensity rainfall, a great volume of runoff was collected in the reservoir. Twenty days after this event, the total volume of water decreased by 1,000 cubic meters due to evaporation losses alone.

Concerned with this problem, CPATSA decided to introduce into the system the idea of a compartmented reservoir. Such an idea was developed by Cluff (6) and has proved to be an efficient method of storing water in areas having relatively flat terrain.

Besides minimizing evaporation losses, recent experience at the farm level has demonstrated that on the average 20 hours of bulldozer time can be saved with a compartmented reservoir of 3,000 cubic meters capacity. This is due to the fact that a more convenient place for dumping the excavated earth is created.

Figure 6 presents a schematic design for the arrangement of the most common crop consortium used by the farmers. With this approach a great flexibility is created for water management (7).

Microcatchment Water Harvesting

Through the small-scale water management program, CPATSA has been looking for different alternatives that will fit the existing varieties of situations encountered at the farm level.

Since specific land requirements are needed for the design of life-saving irrigation, CPATSA has developed a different approach for using microcatchments in row crops. Figure 7 presents a schematic view of the most promising ones.

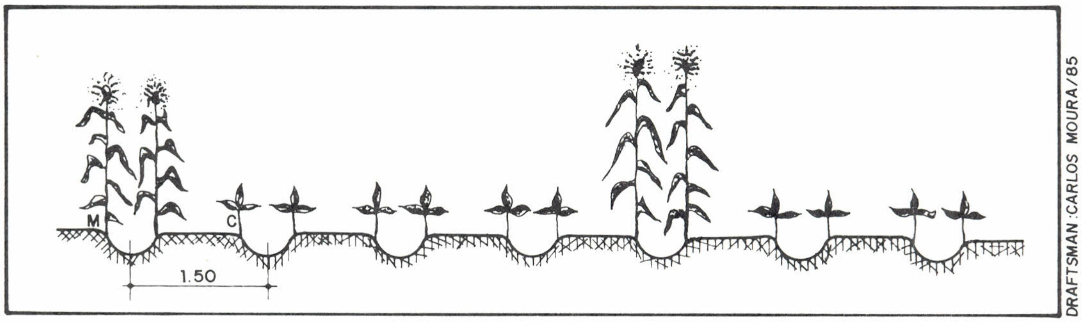

Figure 6. Schematic design for crops in consortium.

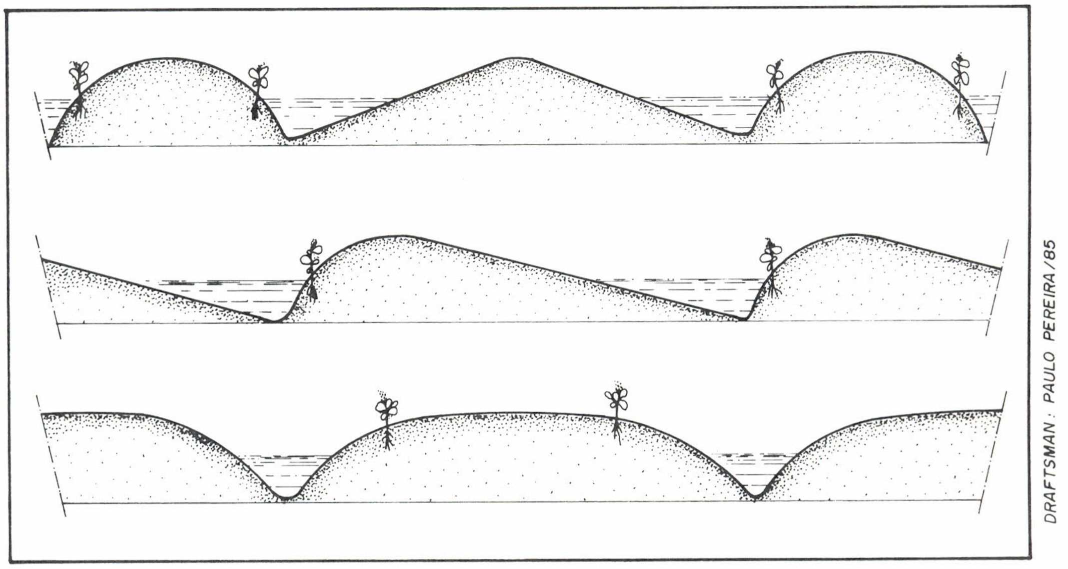

Figure 7. Schematic view of different design approaches for row crops using microcatchments.

The greatest advantages of the use of microcatchments are 1) the production of runoff per unit of area is more efficient, 2) it does not require large machinery, 3) it is easy to implement in the field and 4) it requires low investments. Table 4 presents total costs and returns per hectare for cowpeas with microcatchments.

Experiments carried out at the research station have demonstrated that there is no difference in yields when microcatchments are compared with life-saving irrigation. However, the risk involved is greater. According to experimental results, a 20 percent chance of failure exists.

In the last 2 years, effort has been concentrated on trying to increase the moisture-holding capacity of poor soils by incorporating compost produced with manure and residue of natural vegetation. Also, alternative approaches are being used to try to generate parameters for microcatchment use with trees. Figure 8 presents a schematic design.

Recession Farming

The number of reservoirs existing in the Brazilian semiarid tropics is over 100,000. The importance of those reservoirs is considerable since more than 3 million people depend on them for practicing recession farming (8).

Recession farming is a traditional process of crop production in this region. It consists of utilizing the residual moisture by planting annual crops as the surface water is receding. In this process, the crop is planted without any land preparation, and the planting begins as soon as the rainy season stops.

There are two inconveniences in this method. First, it is necessary to plant early, when the soil is still saturated. As a result, the seed may not germinate. According to some results, the farmer needs to plant several times in order to succeed with germination. Second, in a few days after planting, the soil dries out and the crop will be under stress.

Through its research program, CPATSA has developed a simple practice that can handle such problems. The method consists of constructing mounds or ridges following the contour level after the water recession (9). Figure 9 shows how the process is used.

This method of land preparation permits an earlier planting since the ridge drains the excess water, and the farmer can irrigate later in the season by using the furrows formed between consecutive mounds. According to some results generated at the farm level, the yield using this practice is 154 percent greater than the traditional one for sweet potatoes (9).

Clay Pot Irrigation

History clearly demonstrates that the utilization of clay by rural communities has been notable in the developing countries. In the Brazilian semiarid tropics, the history is not different. There, it is quite common to find entire communities living by producing clay articles, mainly in areas with low annual rainfall.

This was the kind of reality that inspired the studies at CPATSA for utilizing clay pots as an irrigation system.

As an irrigation method the clay pots can be used at varying levels of sophistication, and the equipment can be locally manufactured. At its simplest level, pots can be individually used to water trees or groups of annual grains and vegetables. In such cases, pots are buried in prepared holes with favorable soil texture, and the seeds are planted close to the pots (see Figure 10 for detail).

Variation in the texture of the soil in the hole, and the type of clay used in the pots, determines the rate at which water seeps out of each container.

Good yields have been achieved using pots, with 15-liter capacities. With the help of organic matter, the water release can reach 10 liters per day. The average for vegetables is around 3 liters per day.

This kind of irrigation method is already being used on farms with help from the rural extension service. The greatest advantages of this system are that it is simple to maintain and provides a high water use efficiency.

Table 4. Total costs and returns per hectare for cowpeas with microcatchments.

	Unit[a]	Quantity	(U.S.$) Value
Land preparation	H/M	8.0	85.00
Labor	D/M	35.0	40.00
Seeds	Kg	10.0	14.00
Fertilizer	Kg	250.0	22.00
	Total variable costs		201.00
Yield	Kg	800.0	
	Total value product		290.00
	Net income		89.00

[a]H/M = machinery hours; D/M = Man-day.

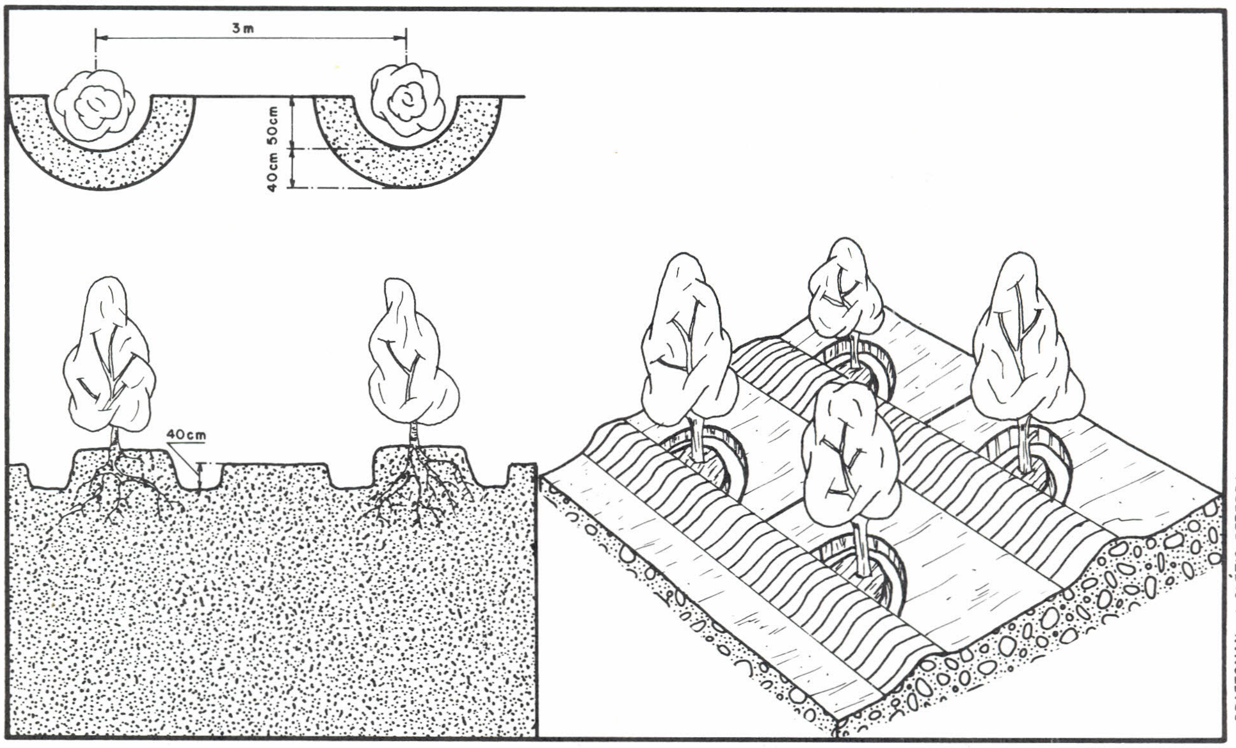

Figure 8. Schematic view of a microcatchment system for perennial crops.

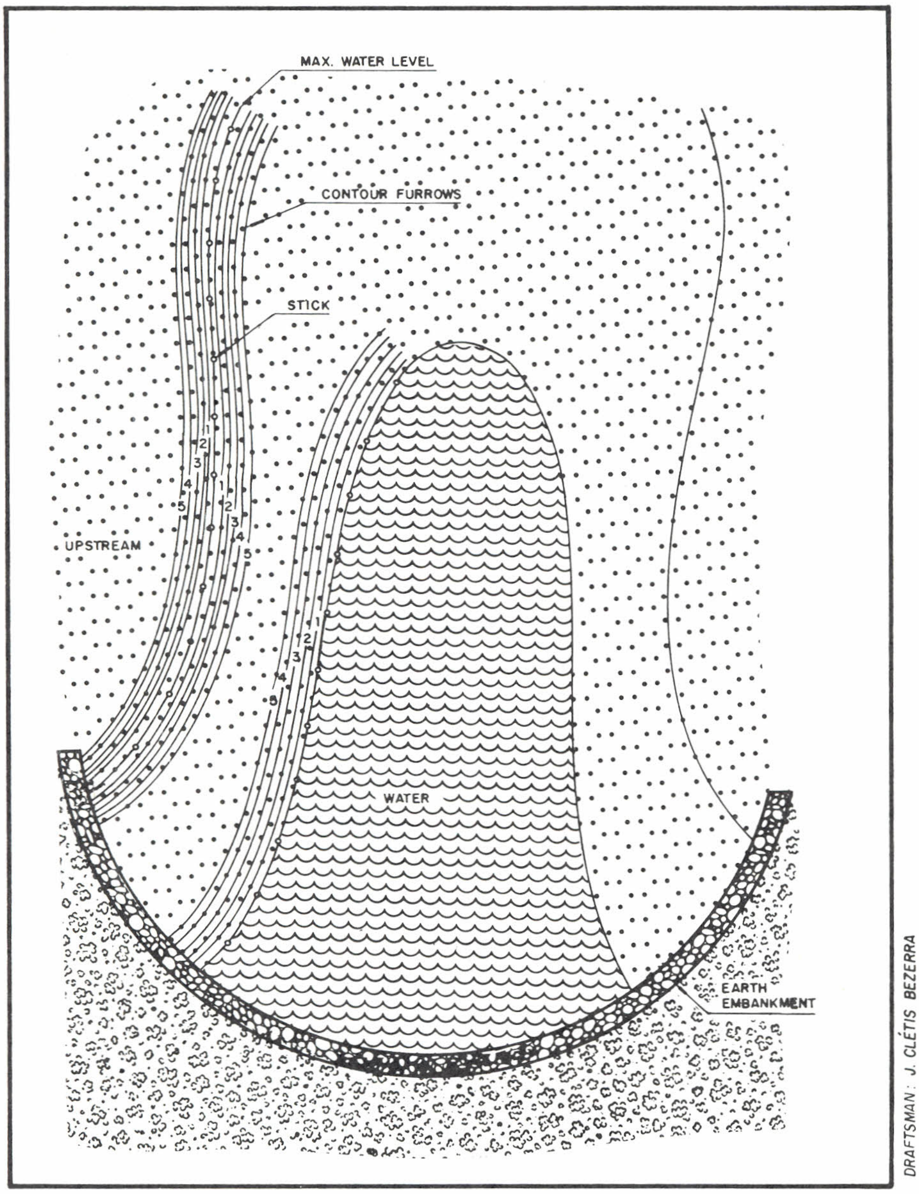

Figure 9. Schematic view of improved recession farming developed by CPATSA.

FARMING SYSTEMS AND TECHNOLOGY TRANSFER

Background

CPATSA was created with the objective of generating new technologies to improve the quality of life of the farmers of this region. Migration from county to town takes place to a large extent all over Brazil, but in the semiarid tropics the rate of occurrence is extremely high. Among other reasons, those for migration are low income and unstable production. Those points are clear in the minds of all participants in the research group.

The analysis of all activities carried out on the small farm aims to understand the existing constraints and interactions among them. Therefore, farming systems research is important for CPATSA.

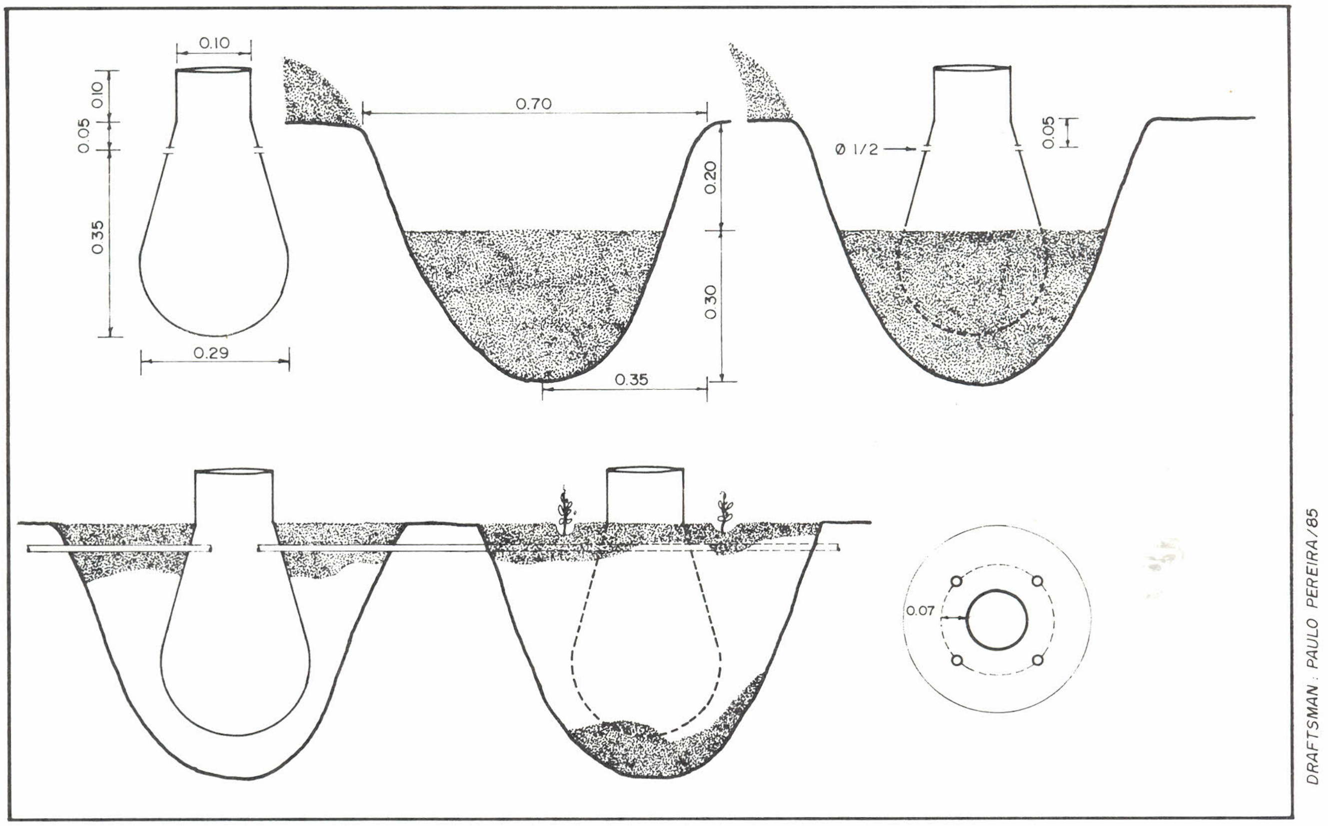

Figure 10. Schematic view of the installation of clay pots.

Complicated environmental processes, such as those that occur in the semiarid tropics, do suggest the need for understanding. Some phenomena may involve several physical variables. Because of this, CPATSA put more emphasis on the single-component approach in its research program.

The situation is changing. During the years to date, CPATSA gathered information and generated alternatives that can make agricultural production more stable and more productive.

Research by itself suggests a dynamic approach. Now it is being realized that the ability to produce high yield does not necessarily guarantee that an alternative will be accepted by the farmers. Therefore, in the last few years CPATSA has been putting strong efforts into the farming systems approach as a research tool not only to demonstrate the effect of new technologies, but also to facilitate later their implementation throughout the region.

Goals for Arid Lands

The semiarid tropics in Brazil is the kind of environment in which plus or minus 10 millimeters of rainfall or 10 centimeters of soil profile can make a significant difference in the production system. However, small-scale water management can overcome many of the natural resources constraints, particularly as they affect rainfed agriculture.

Low effective use of rainfall and erosion are the two major problems in an unimproved farming system. Their effects include complicated changes in the environmental processes. This can induce over the long-run the eventual abandonment of the land.

Farming Systems Research (FSR) is a broad term used to identify any type of research that utilizes a whole-farm approach (10, 11, 12, 13). The farming systems approach is the need for today. However, because of the limitations in the natural resources and the interactions among activities involved in farming in the arid and semiarid zones, planning a farming system is a complex and difficult task; therefore, clear specification of the objectives to be attained by FSR is required.

Besides improving productivity and stability for rainfed agriculture, small-scale water management and related technologies are extremely important in preserving the environment. However, their application still can involve a great portion of a farm's budget. A small farm with poor soil and without any source or kind of storage for water may require a greater amount of capital to be developed in the short run than it can support. Therefore, in such a case, an accepted objective for the FSR can be the development of a plan, including application of improved technology, that can bring such a farm to a modest level of prosperity.

In farming system planning, it is important to recognize that small farmers do not have enough economic support to withstand investment failure, particularly those marginal farmers who produce most of the food. Thus, all components need to operate well if the system as a whole is to have the desired effect.

In such vulnerable farm types, modifications of the traditional system may lead to complexities. So, to apply improved technology, the FSR approach is required as a systematic procedure through which all information related to constraints, available resources, farmers' needs and possible results can be evaluated. Finally, this mechanism also can be helpful in identifying policies or factors that may limit the application of improved technologies.

CONCLUSIONS

Water can be considered a key factor in the farming systems of Northeast Brazil since it is involved in almost all activities on the farm. Small-scale water management can significantly increase the quality of life of the peasant farmers of the Brazilian semiarid tropics.

Low effective use of rainfall and erosion are the major natural constraints in this region. Both problems are related to water. Therefore, small-scale water management seems to be an excellent foundation for supporting Farming Systems Research.

Experience shows that small farmers in arid lands have a great financial problem. In this circumstance, a vicious cycle of low investment and low returns is encountered. On the other hand, the application of small-scale water management may involve a great part of the farmer's budget. Therefore, making such water management viable is the greatest challenge for Farming Systems Research in arid lands.

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