LAND DRAINAGE IN GUATEMALA

E.A. Vanegas Chacón[1] and J. Vos[2]

[1] *San Carlos University, Agronomy Department, Guatemala City*
[2] *ILRI*

Introduction

The current population of Guatemala is estimated to be 11 million, 6.5 million of whom live in rural areas. The annual increase in population is estimated to be 2.6%. To meet the food requirements of this growing population, it will be necessary to increase the area to be cultivated as well as the productivity of the already cultivated areas.

The possibilities of increasing the agricultural area and increasing the productivity in existing agricultural areas are limited by climate, topography, infrastructure, and the lack of money and planning. Potentially highly productive lands are found in the low-lying areas along the Atlantic and Pacific coasts, and along rivers and lakes. These areas, however, suffer from permanent or temporary flooding due to high rainfall and deforestation in the higher reaches of the catchments. Other areas suffer from high groundwater levels for shorter or longer parts of the year.

Flood protection measures and land drainage therefore rate high among the possible measures to increase agricultural production. Such measures serve additional purposes as well: health, afforestation, accessibility, and recreation. Flood protection measures normally require a large-scale and well-planned approach to river-basin development, resulting in high government expenditure. A smaller initial step is to improve crop production by the implementation of drainage facilities in existing agricultural areas, in particular where high watertables can be controlled by surface or subsurface drainage.

In 1968, a National Drainage Programme was launched. This was intended to reclaim and improve agricultural areas through drainage – first in the southern coastal areas, followed by a second phase for the north-eastern and northern areas. Unfortunately, this programme was never fully implemented. The first agricultural drainage project was undertaken in the early seventies in the Laguna de Retana Crater in Progreso (in Jutiapa Department), where 1000 ha were made fit for permanent agricultural use. Twenty years later, the *Dirección de Riego y Ave-*

namiento (DIRYA) formulated an Irrigation and Drainage Master Plan, in which plans for potentially flooded areas were foreseen. The Master Plan distinguished three different situations:

- Temporarily flooded areas;
- Permanently flooded areas; and
- Areas where no distinction between the two could be made.

The total affected area in this Plan was estimated at 209 420 ha.

After a Dutch mission visited Guatemala in 1991, a limited co-operation programme was started between Guatemala and The Netherlands to lend assistance to the above-mentioned Master Plan, to conduct a case study in the valley of the Polochic River, and to implement a programme of capacity building in land drainage at the Agronomy Department of the University of San Carlos in Guatemala City from 1991 to 1997. ILRI has been especially engaged in this training activity (together with the IHE, Delft), which has resulted in ten staff of the Agronomy Department and of DIRYA being trained abroad in natural resources management and in more than 70 local engineers receiving post-graduate training in flood control and land drainage over a period of four years at the Agronomy Department.

An overview publication was issued in October 1998 (Vanegas Chacón 1998), from which the present article has been derived.

Hydrological Conditions

Average annual temperatures in Guatemala fluctuate between 15 and 25° Celsius, with the higher temperatures along the Pacific coast in the south and to a lesser degree in the north-eastern coastal area. Both areas have a high humidity. The higher altitude of the volcanic centre of the country and the east is typically cooler and less humid. Evapo-transpiration there ranges from 750 to 1000 mm during the dry season. In the north-east, we find values of 750-800 mm, in the central plateau, about 850 mm, in part of the northern areas 900-950 mm, and along the Pacific 950-1000 mm.

Most of the rainfall in Guatemala stems from the rising wet air masses that enter from the Atlantic Ocean. Precipitation of 4000 mm per year or more is found in the north-east along the Gulf of Honduras, in the central-north area of Alta Verapaz, around Huehuetenango in the Cuchumatanes mountains, and in the south-east, starting from the area of Escuintla. Annual precipitation of around 2000 mm or less is found in a stretch that covers the Departments of Totonicapan, Guatemala, El Progreso, Jalapa, Chiquimula, and the general south-east. The same rainfall is also found in the Petén area.

The rainfall is captured in 35 hydrological catchments, from which the main river basins discharge their flow either towards the Pacific or the Atlantic Ocean. The divide between these two main directions of flow is formed mainly by the Sierra Madre. The area that drains towards the Atlantic Ocean (about 107 000 km^2) can be split into an area discharging towards the Gulf of Mexico and a slightly larger area that drains towards the Gulf of Honduras. In the first, rivers rise in the higher parts of the Cuchumatanes mountains or in the high areas of the Petén, from where they flow under a relatively low average slope towards the northern coast of the Isthmus of Tehuantepec in Mexico (e.g. Río Chixoy, Río Usumacinta). River discharges can vary considerably (e.g. in the rivers draining towards the Gulf of Honduras). The seven basins in this group include the Río Motagua (the largest river in Guatemala), Río Polochic, Río Cahabón, and the Río Dulce. The river basins that drain towards the Pacific (to-

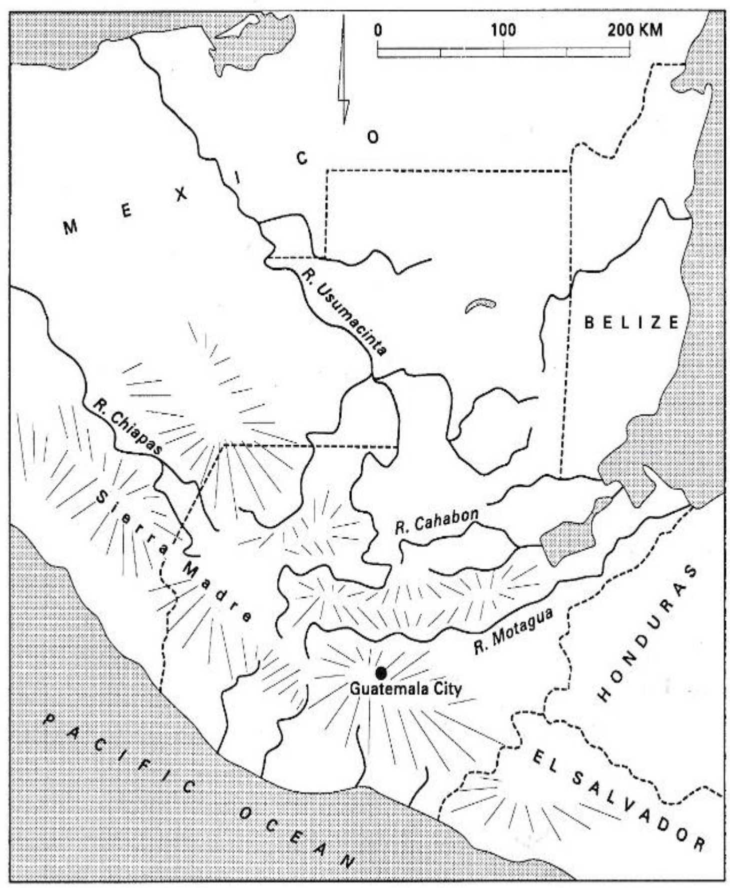

Figure 1. Map of Guatemala with main rivers

talling about 24 000 km^2) are characterized by a steep gradient in the upper and middle reaches, which drops suddenly when reaching the coastal plain. Some of these rivers first flow into Mexico (Río Suchiate) or El Salvador (Río Paz).

Each year, the hydrological process and the basin morphology lead to different problems in land drainage (compare INSMV 1994), one of which is high surface runoff leading to erosion. River discharges can be very high and can cause more damage if the gradient is higher. In the Pacific drainage basin, mean annual discharges are about 70 m^3/s in the lower reaches. Rivers flowing towards the Gulf of Mexico may carry average flows of 250 m^3/s (Río de la Pasión) up to 1700 m^3/s (Río Usumacinta). Annual discharges of the Cahabón and Motagua Rivers, flowing towards the Gulf of Honduras, are 160 and 300 m^3/s, respectively. Values for shorter periods differ considerably from these annual averages and the effect on agricultural areas in the various river valleys must be determined more on the basis of a statistical analysis of historical records of daily values, rather than on averages. Problems of flooding are aggravated by the occasional occurrence of hurricanes and tropical cyclones. Very heavy floods were recorded in 1929, 1933, 1949, 1969, and 1971. Of course, such disasters cause far greater problems than only the loss of agricultural production, and are impossible to prevent. However, the slightly less destructive annual floods also cause continuous damage, and there may be scope in trying to control them to a certain extent, if their character is known and if they can be predicted.

For the latter purpose, the behaviour of a river and its basin must be studied in terms of hydrology, geology, and morphology. Above all, it is necessary to have a long enough historical record of river flows and previous floods and concurrent meteorological records. Since 1960, a number of deterministic hydrological models have been developed, which could be used to simulate river behaviour, depending on rainfall, basin characteristics, soil moisture, etc. (Sandoval and Chavarría 1998). Such models can not only assist in predicting the hydraulic behaviour of a river, but could also be used as a tool for the planning of control works (what would be the effect of certain measures?) and for river-basin management (what actions could be taken to minimize certain risks?). One of the problems is that such models require exhaustive data, which may not be available.

Even if simulation models could be helpful, solving flooding problems would mean the construction of extensive flood protection works (e.g. dikes, storage reservoirs, and increasing river cross-sections). Such measures require not only careful project studies at the appropriate levels and to the proper standard, but also a considerable amount of government expenditure.

While the latter situation may be difficult to realize at short notice, it may be possible to introduce some drainage measures on a smaller scale, say at the farm scale or slightly larger. Let us now look at such agricultural drainage projects in the country.

Agricultural Drainage Projects

Generally, drainage forms part of an agricultural development project, whose planning and implementation is a multi-disciplinary undertaking in which drainage engineering is only one of the required specializations. Depending on the activities that are to be developed in the planning process, various phases can be established, each one with appropriate information that should already exist or that should be obtained from research and detailed studies. Information is required at three project-development stages (reconnaissance, feasibility, and implementation).

The project must be supervised to establish quality control, to take into consideration the costs of operation and maintenance (plans to operate and maintain the project with trained staff, etc.) with the aim to know, through monitoring and evaluation, whether the project is functioning adequately.

An agricultural drainage project can be part of local, regional, or national development. At national level, numerous efforts are being undertaken by governmental and private institutions to urge drainage projects to collaborate in reclaiming over 200 000 ha that are permanently or temporarily flooded. Examples of main drainage projects that have been formulated are:

- The National Drainage Programme (started in 1968);
- The Flood Control Programme (started in 1988);
- The Valle del Polochic Development Project (1991);
- The Caserio La Blanca Drainage Project (1995); and
- The Nuestra Cuenca Project (1996).

The main objectives of the implementation of drainage projects in Guatemala are:

(i) To increase agricultural production, with emphasis on bananas, sugarcane, rice, vegetables, and staple grains, thus contributing to the short-term food security in Guatemala and to the long-term agricultural diversity;

(ii) To improve the standard of living of the neighbouring communities through the creation of jobs resulting from the intensification of agriculture.

Notwithstanding the fact that there has been little study done in Guatemala on drainage as an effective method of maintaining a sustainable agricultural system, many private undertakings have invested time and capital in improving drainage, so as to avoid economic losses due to flooding of rivers or to poor field drainage. Below, we shall look at a few examples of such undertakings.

Drainage and the Cultivation of Bananas

Bananas are cultivated in the zones of the humid forests along the tropical coastlines of the Atlantic Ocean (Izabal Department) and the Pacific Ocean (Escuintla Department). They are grown at altitudes of not more than 100 m. The principal varieties are Gran Enano, Cavendish, Valery, and Gran Michel. Yields are up to 128 tonnes per ha.

One of the most important factors in establishing a banana plantation is water management. In badly drained areas, for example, the rhizome of the banana plant produces an abundance of aerial roots and is raised from the soil. The plants are poorly developed, show premature yellowing of the older leaves, and a pale discolouring of the younger ones, due to the low decomposition rate of the organic matter and the low mineralization rate of nitrogen in waterlogged soils. Bad drainage also limits the growth of the roots, and the roots die when they reach the watertable. (This agrees with local experience, which is that the roots die after being in contact with ponded water for 48 hours.)

The standard system in the drainage of bananas consists of:

- Tertiary drains with a bottom width of 0.30 m and a slope of 1%, which flow into a secondary drain. Usually, the tertiary drains are excavated by a tractor equipped with a trench excavator, which banana growers refer to as a *gallinita* ('little hen'), because when excavating the drain it spreads the earth back along the sides of the drainage canal;
- Secondary drains with a bottom width of 2 m, of varying length, and spaced 100 m apart, which flow into the main drain. The secondary drains are excavated by tractors equipped with buckets whose blades can be angled according

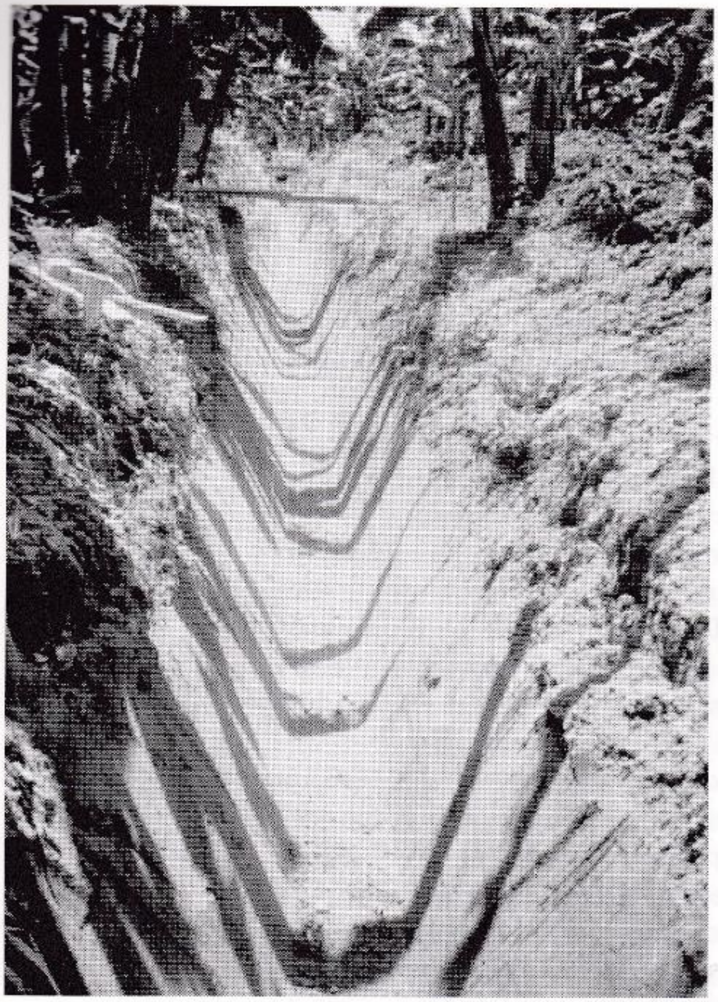

Figure 2. Secondary drain in a banana plantation in Izabal

to the texture of the soil. The most common side slope is 1:3; (see Figure 2).

- Main drains, with a bottom width of 5 m, of varying length, and spaced at 500 m. These are excavated with back-hoe equipment. Their function is to collect the effluent from the secondary and tertiary drains and to carry it away from the cultivated area. On the Atlantic coast, the drain effluent flows towards the Motagua River, which drains into the Gulf of Honduras. For the new banana plantations on the south coast (Tiquisate Department), the effluent of the main drains flows directly into the Pacific Ocean.

Although theory dictates that the system layout should be based on the physico-chemical properties of the soil, the criteria seem to have been strongly influenced by the practical aspects of the work organisation on the banana plantations. This explains why the fields are 100 m wide, with an automatic transportation cable in the centre. Labour laws dictate that bunch-cutters do not have to walk more than 50 m with a cut bunch on their shoulders.

For a typical open drainage system as described above, it can be calculated that an area of 400 m x 200 m requires approximately 6750 m^3 of excavation. At a price of U.S. $ 1 per cubic metre and adding $ 1250 levelling and installation costs, we find that the installation of this system costs about $ 1000 per hectare.

It is important to mention that the banana plantations in Izabal Department have pioneered the development of drainage in the low-lying areas of the Motagua Basin, and indeed nation-wide. Many hydraulic structures (e.g. canals, dikes, pumping stations) have been developed in the Motagua Valley. Owing to the correct implementation of this type of drainage system, there have been large increases in the production of bananas. Also the banana plantations have done a lot of research, which has provided basic information on the use of drainage as a technique in banana growing. They are currently investigating the high-density sowing of young banana plants of low-yielding varieties (Israeli varieties) with intensive drainage systems to increase the productivity per unit area.

A classic example of agricultural drainage in a banana plantation is known as Bandegua. It is a plantation of 1700 ha, located between bends of the Motagua River, and is protected by dikes. It uses a pumping station with seven pumps, each 250 hp, with a capacity to pump 50 000 m^3/h (equivalent to about 70 mm/day). This makes it possible to maintain the watertable in the cultivated area at a level independent of the water levels outside the dikes. Bandegua constitutes the biggest polder in the country.

Drainage and the Cultivation of Sugarcane

Sugarcane was introduced into the New World by Christopher Columbus in 1493. During his second voyage to America, Columbus brought with him to the island of Hispaniola varieties of the perennial grass *Saccharum*, namely *S. sinense R.* and *S. barbari J.*, which are characterized by slender stalks and low yields. It was not until 300 years later, in 1791 – when William Bligh (British Naval Officer of *Bounty* fame) transported varieties of *S. officinarum L.* from Tahiti to Jamaica – that the production and industry of sugarcane could support itself in the Central American region.

At present, sugarcane is cultivated in Guatemala in the humid forests of the tropical and subtropical regions along the Pacific coastline, especially in the Departments of Retahuleu, Suchitepequez, Escuintla, and parts of San Marcos, Quezaltenango, Santa Rosa, and Jutiapa. Guatemala is one of the five major producers of sugarcane in the world, with more than 20 sugar mills ('*ingenios*') on the southern coast alone. A cane plant can live for about five years and the average annual production is about 90 tonnes/ha. A tonne of cane will yield an average of about 170 pounds of sugar.

Even though drainage is not considered to be indispensable to cane-growing on the right type of soil, its implementation has produced great benefits for cane-growers, among which are:

- Drainage makes it possible to control infestations of spittle bugs (*Aneolamia sp.*). Sufficient aeration of the soil due to proper water levels contribute strongly to the control of infestations;
- Drainage increases the workability of soils in the rainy season, when soil preparation takes place to prepare seed nurseries to renew the cane plants;
- Drainage increases the cane yield in low-lying areas by 10 to 30%, probably because of improved aeration of the soil;
- Proper drainage can reduce the use of nitrogenous fertilizer.

The techniques used are based on local experience, together with criteria based on physico-chemical properties of the soil. Main drainage and maintenance measures in most of the cane plantations on the Pacific coast are:

- Square fields (250 m x 250 m) between lateral drains, which are excavated with a triangular mouldboard plough. The drain depth is 0.30 - 0.40 m, with a side slope of 1:2;
- A main drain spacing of 500 m with a drain depth of 2.5 m, a bottom width of 2 m, and side slopes of 1:2, excavated by back-hoe;
- Annual maintenance of the drainage systems from July to September, the period in which there is no harvesting or sugar processing.

At present, many sugar mills are renewing the traditional system of sugarcane cultivation. On the *Costa Sur*, flood control and land drainage have gained much in popularity. Some experiences are:

- The construction of spilling basins to control floods, especially in the areas along the banks of the Coyolate River;
- The use of groundwater by excavating ponds (25 m x 75 m, with a depth of 3 m) as a source of supplementary irrigation water in the dry season and as a drainage well to lower the watertable in the bordering areas in the rainy season. This is an application of the concept of vertical drainage and its conjunctive use;
- The development of polder systems in low-lying areas. Examples are found in the cane plantations along the Naranjo River, where a dyke was constructed along the length of the river bank and the excess water from high water levels is pumped back into the river (see Figure 3).

Figure 3. A pumping station in a sugar-cane polder along the Naranjo River on the south coast (Escuintla Department)

Drainage and the Cultivation of Rice

Rice production in Guatemala is very important as it is one of the dietary staples of Guatemalans (together with maize and beans). Traditionally, the most widely cultivated varieties in the tropical and subtropical areas along the Atlantic and Pacific coasts have been Blue Bonnet, Blue Belle, Tikal 2, and Star Bonnet. The average yield is 4000 kg/ha.

Today, in conformity with the policy of the Ministry of Agriculture, Animal Husbandry, and Food, to allocate national territory according to best land use, the cultivation of rice is important in those areas that present severe problems of partial or total flooding (i.e. relatively flat and low-lying areas along coasts and lakes). As most rice fields are flooded during the growing season and drained to allow harvesting, rice is the crop *par excellence* to be cultivated (e.g. in the lower areas of the Polochic River Basin).

Rice can be grown on terraces or in paddies. Terraces often have a minimum width of 12 m, a maximum vertical level difference between two adjacent fields of 0.10 m, and a bund height of 0.50 m with a 1:4 side slope. It is important to understand that by applying this method, excess water will drain from higher-lying terraces to lower-lying ones. Paddies are mostly square fields (of some 50 m x 50 m) surrounded by bunds of 0.50 m height. Paddies drain into an open ditch, which conveys the excess water to an evacuation point (river or lake), either directly or via secondary drains.

For the low-lying areas in the Polochic River Basin, the use of a pumping station to drain the rice fields before harvest would be necessary, and it is recommended that the cost of pumping be included in the feasibility study of a rice project in this zone.

Flood Protection and Agricultural Production in the Highlands

The Andes in Guatemala splits into two ranges: the Sierra Madre and the Sierra de los Cuchumatanes. In the latter lies the Chemal, the highest crystalline mountain in Central America, with an elevation of approximately 3800 m. (Only some volcanoes in Guatemala are as high as 4200 m.) The Sierra Madre runs across Guatemala from west to east and its central part is a plateau, the *Altiplano Central*. Guatemala City, the capital, is located there. These mountain ranges make up 75% of the country's total area, and 50% of the agricultural area used for staple food production (maize, wheat, green beans, broad beans), vegetables (potatoes, peas, beets, cucumbers, courgettes, string beans), berries (strawberries, raspberries), and fruits (peaches, plums, apples, pears). These products, which contribute to the diversification of Guatemalan agriculture, are called non-traditional export crops.

The almost flat *Altiplano* is over-populated, which is exerting pressure on soil resources. The clearing of forests to cultivate areas with steep slopes has exposed the top soil and has caused serious erosion. Annual soil losses in the basin of the Chixoy River, for example, average 2890 tonnes/km^2, and the 2700 ha that are flooded annually in this basin can be attributed to erosion and gully formation. Gullies are the most extreme indication of severe soil erosion. In the Quiche language, these are known as *siguanes*, a word that also means 'ravine', which gives an indication of the magnitude of the erosion problem. The best flood-control measures therefore are not so much the evacuation of excess water through drainage, but rather the control of erosion and the prevention of gully formation. The latter can be done at two levels:

- On a gentle slope or in a drainage basin, through avoiding surface runoff or to control it totally and allow it to infiltrate uniformly. Appropriate methods of soil and water conservation are replanting pastures and woods, constructing infiltration ditches, and applying absorption terraces, contour furrows, and diversion ditches;

- In the gully, check-and-drop structures across its width will slow down the flow of water and encourage the settling of soil particles in suspension. Sand-filled bags, reinforced with stones, branches, and poles could be used. The spacing of these structures is important. The Chixoy Project has a special component to tackle soil deterioration due to gullies, involving surrounding communities to rescue 39 locations that are seriously affected.

Summary

In Guatemala, drainage is to a large extent linked with flood protection. The main concern is how to prevent damage from high surface runoff and excessive river flows that result from high rainfall. Floods affect potentially highly productive agricultural land that could be reclaimed if floods could be controlled. Despite early identification of problem areas, progress in combating inundations was initially relatively slow, but has gained momentum in the nineties.

In accordance with governmental policies of land allocation according to land suitability, the agricultural potential of areas that are subject to permanent or temporary flooding is high. They could be made suitable for growing various species of *Salicaceae*, for pasture, and for rice cultivation. These areas lie in coastal and lake shore plains and in river beds, and can only be developed fully – with minimum environmental damage – if proper drainage techniques are employed. External river control needs to be combined with in-field drainage and, often, with pumping.

In the agricultural sector, there is a wide social acceptance of drainage projects owing to the fact that in many cases the investment costs have been superseded by the benefits. Among these are: increased agricultural production, especially of bananas, sugarcane, rice, vegetables, and staple grains, contributing to the short-term food security of the Guatemalan people and to the long-term diversity of agricultural production. Drainage also improves the standard of living in the communities near the projects because of the creation of jobs through agricultural intensification in zones that were formerly non-productive.

Land drainage in Guatemala is linked to the historic development of banana cultivation on the Pacific and Atlantic coasts, attaining its culmination today in the banana plantations in the low-lying areas of the Motagua Valley. Drainage is included in

modern sugarcane growing, where it has proved to be indispensable in the control of infestations of such pests as spittle bugs (*Aneolamia sp.*), and to be the deciding factor for the increase in sugarcane yield in low-lying areas through improved soil aeration. Drainage is also important in low-lying areas where rice is grown, notably before the harvest. Examples can be found along the Polochic River.

In the Guatemalan highlands, flood protection plays an important role through the implementation of soil conservation measures, which reduce surface run-off and permit the adequate evacuation of excess water without causing erosion and loss of topsoil.

The technique of vertical drainage in the *pozos someros* (or 'shallow wells') is in a pioneering phase. It tries to combine the control of groundwater levels in surrounding lands and the utilization of groundwater for supplementary irrigation of the alluvial lands on the south coast.

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