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SOIL AND WATER MANAGEMENT FOR BANANAS AND PLANTAINS IN THE WINDWARD ISLANDS

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ABSTRACT

About 22,000 farmers in the Windward Islands (Dominica, Grenada, St. Lucia, St. Vincent) supply bananas for export to Europe on a weekly basis. The terrain is mountainous, with more than 50% of banana fields having slopes greater than 20 degrees. The soils are all volcanic in origin with relatively high clay contents and, although not highly erosion-prone, the combination of steep slopes, intense rainfall and bare surfaces can lead to serious erosion. Banana cultivation is often blamed for soil erosion and siltation of streams but, managed properly, stands of bananas and plantains offer excellent protection for the soil. Low-cost operations like minimum tillage, effective drainage, thoughtful use of plant litter and maintenance of Vetiver grass lines all contribute to effective soil and water management in this cropping system.

INTRODUCTION

The banana industry of the Windward Islands (Dominica, Grenada, St. Lucia and St. Vincent) is tiny in terms of total world trade in bananas; just 3% (Borrell and Yang, 1990). Yet this amounted to 274,539 tonnes in 1992, with a value of US$140.9 million (WINBAN, 1993a) which is equivalent to 15.1% of the islands' GDP. These bananas are produced by 24,655 registered growers from 41,700 acres (16,876 hectares) giving average yields of only 6.58 t $acre^{-1}y^{-1}$. This is poor by world standards. Stover and Simmonds (1991) report yields of 68 t $ha^{-1}y^{-1}$ (27.5 t $acre^{-1}y^{-1}$) from plantations in Honduras and Costa Rica where soils, climate and management (including irrigation) are optimal.

The relatively low yield of bananas in the Windward Islands (WI) is partly an artifact of the way in which the figure is calculated. Fields drift in and out of production all the time and there is no accurate register of the area planted, so the estimate of 41,700 acres may well be too high. Nevertheless, the potential production of bananas is seldom achieved, although yields from trials conducted by WINBAN throughout the islands, using a proven package of recommended practices (WINBAN, 1993b), are usually in the range 15-23 t $acre^{-1}y^{-1}$. Yields are constrained by a combination of environmental and management factors. Reid (1993) has summarized the main physical constraints: poor soils, steep slopes, high winds, drought, inter-mat competition, flooding/waterlogging, pests and diseases. Exacerbating these problems is an interaction between poor farm management skills and expensive, scarce labor resulting in very low levels of labor productivity (Matthew, 1992; Alexander-Louis, 1993).

Of the environmental factors mentioned above, sub-optimal soil physical conditions have often been implicated as a major cause of low productivity (eg. WINBAN, 1991). All soils in the WI are volcanic in origin, parent materials being predominantly basalt, dacite and andesite. The proportion of clay in soils is high with most important arable soils in the clay and clay-loam textural categories. The predominant clay minerals vary between islands and with altitude (and hence rainfall) within islands. In the high rainfall areas of St. Vincent and Dominica allophanic soils are common whereas kaolinitic soils dominate the high altitude soils of Grenada and St. Lucia. Allophane soils are found at mid- and low altitudes in St. Vincent while soils in the other islands become kaolinitic and then montmorillonitic as one descends to sea level. Some of the most fertile soils are alluvial deposits along the lower reaches of river valleys, particularly in St. Lucia.

Although the soils are not, in themselves, particularly erosion-prone, the combination of heavy, intense rainfall and steep slopes makes runoff and soil erosion a real danger. More than 50% of all banana fields have slopes of more than 20° and much of the banana production is on marginal land. There is little hard evidence that banana production is exacerbating the problem of soil erosion in comparison with other crops but, given the widespread distribution of the crop and its association with sensitive areas, it would be prudent to try to ensure that erosion is minimised.

Soil conservation measures are seldom popular with farmers because measurable benefits are not usually gained in the short- to medium term. Approaches involving engineering works eg. embankments and terraces are particularly unpopular in the WI because of high costs, both initially and for maintenance. However, it is feasible in a productive, humid tropical environment to rely on "soft" biological technologies which are cheaper and more user-friendly. Examples of these are:

1. the use of crop residues as a mulch and soil cover to protect the soil surface from raindrop impact and to promote infiltration of rainfall, recycling of nutrients and increase the activity of earthworms

2. planting grass lines with Vetiveria zizanioides (Vetiver grass, khus-khus grass) to slow down the rate of runoff, intercept suspended soil particles and bind the surface layers of the soil with roots.

In this paper I present the results of recent research into these two technologies and discuss various problems associated with their implementation.

CROP RESIDUES AND EARTHWORMS

Banana is a highly productive crop. Stover and Simmonds (1991) reported a probable maximum production of 400 t $ha^{-1}y^{-1}$ fresh weight of above-ground parts under optimal conditions in Panama, with an extra estimated 52 t $ha^{-1}y^{-1}$ of roots and rhizomes. About 280 t $ha^{-1}y^{-1}$ of this material is composed of pseudostems and leaves, equivalent to about 28 t $ha^{-1}y^{-1}$ dry weight. Measurements of crops in St. Lucia, where potential production is lower and crop management is less well developed, show that about 90 t $ha^{-1}y^{-1}$ fresh weight (9 t $ha^{-1}y^{-1}$ dry weight) of pseudostems and leaves are produced. A survey of the amount of this "trash" on the ground showed 7.3 t ha^{-1} dry weight ie. almost equivalent to one year's production and enough to cover the ground about eight times if spread meticulously.

There are numerous benefits associated with maintaining a layer of litter on the soil surface: raindrop- and canopy drip energies are absorbed, thereby minimising soil particle detachment and erosion; infiltration is promoted as the litter slows the movement of surface water; soil temperature is reduced; direct evaporation from the soil surface is reduced; the opportunity exists for recycling nutrients. This latter benefit can only be realised if litter is incorporated into the soil by cultivation or by invertebrates eg. termites or earthworms. In some systems eg. in the French West Indies bananas are replanted frequently and litter is ploughed into the soil. This results in a massive influx of material all at once which stimulates the rapid breakdown of soil organic matter (Godefroy and Jacquin, 1975). Cultivation is also known to reduce drastically earthworm population densities (eg. Hendrix et al., 1992; Marinissen, 1992) which in turn can depress levels of soil organic matter (Lavelle and Martin, 1992) with all the negative effects on soil structure that this entails.

Contrast this with the cropping system prevalent in the Windward Islands where the only cultivation is the excavation of a hole large enough to take the planting material. Re-planting is done every four to seven years, in the same fashion. Since inter-plant cultivation eg. to control weeds is not possible without damaging the shallow banana root system, litter accumulates steadily on the soil surface.

It has been suggested that the physical structure of many banana soils in the Windward Islands is a serious constraint to banana production (WINBAN, 1991; Reid, 1993). In particular, high clay content, bulk densities and soil strength could result in slow drainage and impeded root growth and function. In addition, clearance of tropical forest for arable cropping is known to result in the rapid decline in levels of soil organic matter. Since organic matter content is often highly correlated with indices of good soil structure eg. aggregate stability or erodibility, its reduction is usually associated with structural degradation, erosion of topsoil and a dramatic decline in fertility.

In most environments (eg. the French West Indies mentioned above) these problems could be overcome by regular tillage which would reduce, at least temporarily, bulk density and soil strength and produce a network of pores and soil aggregates more conducive to good root performance. In mature tropical forest, where soil disturbance is at a minimum, litter and its breakdown products are incorporated into the soil by earthworms. These animals are acknowledged worldwide to be the most influential members of the soil macrofauna and there are very many reports in the literature linking them to dramatic improvements in soil structure (eg. Dexter, 1991; Lavelle and Martin, 1992; Edwards and Bater, 1992). Farmers in Europe have long recognized this fact and consider soils containing large numbers of earthworms as soils "in good heart".

So, in the absence of tillage, incorporation of litter and its breakdown products is only possible where healthy populations of earthworms exist. Such continuous incorporation avoids the periodic massive influx of material characteristic of the French system.

A preliminary, small survey was undertaken in St. Lucia to estimate the numbers of earthworms in banana fields and to test the hypothesis that their abundance was related to "trash" (ie. litter) cover. The survey was confined to the Roseau Valley, St. Lucia. Six fields were sampled; two from Model Farms (5-10 m altitude), two from around Vannard (100 m altitude) and two from around Millet (300 m altitude). Four samples were taken from each field; two from areas with trash cover and two from areas of bare soil. For each sample the edges of a 0.5 m x 0.5 m frame, constructed from galvanised steel plate, were pressed into the soil to a depth of 5 cm so as to confine an area of 0.25 m^{-2}. All trash in this area was saved, weighed fresh, dried and weighed again. The top 10 cm of soil was removed from inside the frame and all earthworms were sorted, removed by hand and preserved in formalin solution. Earthworms from below 10cm depth were collected by pouring 10 litres of dilute formalin solution (0.3%) into the frame. This solution acts as a mild irritant and any worms present make their way to the surface within a few minutes. (Only one species of earthworm (name unknown) was found during the survey, and samples were sent to Rothamstead, UK for formal identification. Results are not yet available). Three soil cores were taken from undisturbed areas adjacent to the earthworm sampling point using a stainless steel corer to extract 500 cm^3 of soil from the 0-10cm depth interval. Soil samples were taken to the laboratory and used to determine pH, % organic matter (OM), bulk density and soil water content.

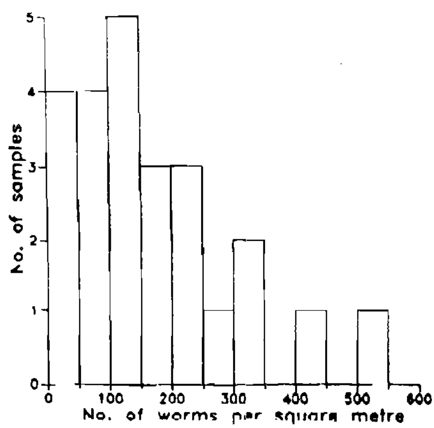

Fig. 1. Distribution of earthworm population densities from 24 samples, Rosea Valley, St. Lucia.

There were no significant differences in the number, the dry biomass m^{-2} or the individual dry biomass of earthworms in relation to altitude (Table 1) or trash presence (Table 2). Worms were found in all samples but variation between samples was large, with numbers ranging from 4 to 516 m^{-2} (Figure 1). There were, however, clear trends in relation to trash presence, with 50% more worms and 65% more worm biomass under trash. The overall mean biomass of 10.35 gm^{-2} was equivalent to more than 0.1 t ha^{-1}, a substantial amount.

Table 1. Variation in earthworm abundance and soil properties with altitude.

Variable	5-10 m	100 m	300 m	Significance
Worms m^{-2}	146.5	204.0	158.5	NS
Worm mass m^{-2} (g)	10.1	12.9	8.1	NS
D.Wt (mg $worm^{-1}$)	67.8	75.2	51.8	NS
Organic matter (%)	2.85	2.54	6.26	***
pH	4.81	3.82	3.99	*
Bulk density (g cm^{-3})	1.09	1.08	0.87	***
Water content (%)	36.4	39.5	54.1	***

Table 1 shows that organic matter content was significantly higher at high altitude whereas pH was significantly higher at the lowland sites. Bulk density was lower and soil water content higher at the upland sites, resulting from the greater rainfall at higher altitudes, but also reflecting the inverse relation between soil water content and bulk density due to differences in soil mineral composition and particle size distribution. Only soil water content was significantly greater under trash than for bare soil, although there were (non-significant) trends in other soil properties. Soil under trash tended to have larger amounts of organic matter, a higher pH and a lower bulk density (Table 2). However, there were no significant correlations between worm numbers or biomass and any of the soil properties measured.

Table 2. Variation in earthworm abundance and soil properties with trash presence.

Variable	No Trash	Trash	Significance
Worms m^{-2}	136.3	203.0	NS
Worm mass m^{-2} (g)	7.8	12.9	NS
D.Wt (mg $worm^{-1}$)	66.5	63.4	NS
Organic matter (%)	3.52	4.25	NS
pH	4.02	4.39	NS
Bulk density (g cm^{-3})	1.04	0.99	NS
Water content (%)	40.0	47.0	*

Some soil properties were expected to vary with altitude (and associated differences in rainfall and soil type) and this was found to be so in this limited, preliminary survey. The hypotheses that earthworm activity results in soil improvement and that activity and soil condition are greatest under trash cover are not supported by the data shown here. Nevertheless, clear trends showing more earthworms under trash were noted. The reason for the large amount of variation in the data is **mobility**, both of earthworms and of trash. Sampling points within fields were chosen on the basis of **current** trash incidence and adjacent bare areas were often only a few feet away. It was not possible to know if trash had recently been where there was now only bare soil, and *vice versa*.

Earthworms are also highly mobile over these distances. The only statistically significant variable with respect to trash cover was soil water content, which largely reflects current conditions. Wetter soil under trash was probably a consequence of a mulching effect.

Despite the small sample size, there were a number of important results from this survey. Earthworm numbers and biomass were found to be quite large in relation to many arable systems (eg.Hendrix et al., 1992) and comparable with those found in four samples taken from a forest site at Millet (200 earthworms m^{-2}, 12.7 gm^{-2} dry biomass). Values for organic matter were also relatively high, comparable in some cases to soils under tropical forest elsewhere (eg. Bhadauria and Ramakrishnan, 1991) although the majority had lower values around 3% perhaps reflecting the more prolonged cultivation and more intensive management at the lowland sites.

Values of pH were extremely low throughout, ranging from 3.2 to 5.9. This survey reinforced the view that most banana soils in St Lucia have become highly acidic (WINBAN, 1993a). Earthworms in general are calcicolous animals and do not normally thrive in acid soils. No relation between earthworm abundance and pH was apparent in the data, however.

Promotion of earthworm activity is easy. They thrive under the same conditions which are conducive to good banana growth. They suffer when soils dry out, when drainage is poor and in acidic soils. They require a regular supply of vegetable litter as food - banana trash appears to be ideal, particularly when spread as a mulch and soil surface protectant. So, normal, good husbandry should result in optimal conditions for earthworms which, in turn, should proliferate and improve soil conditions, initiating and sustaining an upward spiral of sustainable production. In contrast, poor agronomy discourages earthworms and promotes soil degradation. Additional samples taken from a farm where the farmer removes his trash provided only one earthworm from four samples each of 0.25 m^{-2} and soil erosion was severe.

A more serious potential threat to earthworm populations is the widespread use of pesticides, particularly nematicides since many of these chemicals affect respiratory enzymes common to nematodes and earthworms (Lardier and Schiavon, 1989; Reddy and Reddy, 1992). Any future progress on reducing pesticide usage in the banana industry is likely to improve conditions for earthworms.

No earthworms were found which had a relaxed diameter of more than 3.5 mm. The mean diameter of primary roots of banana ranges from 4.4 to 8.0 mm (Swennen et al., 1986; Delvaux and Guyot, 1989) so, although earthworm burrows will promote infiltration, their role as preferred channels for root growth is likely to be restricted to smaller, secondary roots of the banana plant. The intriguing possibility exists that the introduction of larger species of earthworm to the WI might prove beneficial to the growth of bananas.

VETIVER GRASS LINES

Vetiveria zizanioides (Vetiver grass, Khus-khus grass) is ubiquitous in all four islands, having been brought in from India early this century. It was used extensively to protect terraces in sugar cane fields but its use has ceased since bananas replaced sugar as the dominant crop. Relict populations are still found along roadsides and in gardens but it is no longer used as a tool for combating erosion except in high-risk situations eg. road cuttings. A great deal of interest in this species has been shown worldwide in recent years (National Research Council, 1993) and it is seen as an important tool for combatting soil erosion, particularly in resource-poor situations. Its utility lies in its ability to tolerate a wide range of environments, it's close-tillering growth habit and it's non-seeding character.

Conversations with banana farmers reveal their appreciation of Vetiver as a species for erosion control but they are unwilling to use it in banana fields because it takes up too much space which could be used for more banana mats. In addition, they say that it grows poorly under the shade of the banana canopy, seldom persisting for more than a year. These two problems have been investigated at WINBAN R&D and results are presented below.

A well-grown stand of bananas produces a dense canopy. Stover and Simmonds (1991) reported values of leaf area index for banana from 2.4 to 4.7 although these depend very much on variety, planting density and stage of the cropping cycle. A series of measurements was taken under a banana canopy in St. Lucia by repeatedly walking a 40 metre transect through the crop while holding a portable light meter. The crop was a 'Robusta' second ratoon stand, spaced eight feet between rows, seven feet within rows which were oriented east-west. Readings were taken at ground level every two metres and compared with values recorded in direct sunlight.

Mean values of fractional transmittance are shown in Table 3, together with minimum values recorded at each time. Under this particular canopy, which was fairly typical of banana stands in the WI, about 40% (27-65% depending on the time of day) of the incident light reached the ground but this was highly variable, with some areas occasionally receiving only 3-7%.

Table 3. Diurnal variation in transmission of light through a banana canopy.

Time	Mean fractional transmission	Minimum fractional transmission
0830	0.33	0.04
1030	0.65	0.06
1230	0.52	0.07
1430	0.27	0.03

If Vetiver is to flourish with bananas, it must be shade-tolerant or the banana canopy must be manipulated to allow more light to penetrate to the understorey. The growth of the Vetiver clone available in St. Lucia was tested under a range of shade conditions. Three tillers or "slips" were planted in each of 80 plastic pots each containing 2.5 litres of a clay-loam soil taken from the WINBAN farm. Two replicate blocks of four shade environments were constructed using various combinations of shade netting suspended from wooden frames to give mean daily shade values of 7%, 35%, 60% and 75% of incident light. Ten pots were allocated at random to each shade/block combination. Since many of the banana soils in the WI are acidic, and this soil had a pH below 4.0, five of the ten pots in each shade/block combination were limed, using ground calcitic limestone, at a rate equivalent to 8 t ha^{-1}. The experimental design was thus a randomized complete block with two blocks and four shade treatments, incorporating a split-plot treatment of with/without limestone. Pots were kept well-watered and the Vetiver was allowed to grow for 140 days after which it was harvested. The number of tillers was counted and fresh- and dry weight of the shoots were measured.

Figure 2 shows the inhibition of shoot growth when Vetiver is grown in shade and the difference that the addition of lime to this acid soil made to this response to shading. Analysis of variance showed that the effect of shading was highly significant (P=0.004) whereas the effect of liming was not. Nevertheless, the effect of lime was very consistent across all shade treatments. The mean dry matter production at 60% shade (ie. a fractional transmission of 0.4 in Table 3) was only about 45% of that in full sunlight.

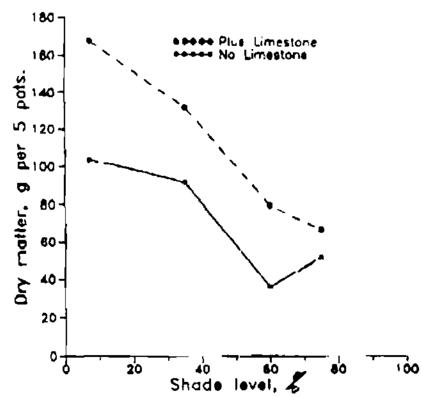

Fig. 2. Aerial growth of Vetiver grass under different levels of shade.

Differences in shoot dry matter were directly proportional to the number of tillers produced (Figure 3). This is important because the ability to filter surface-flowing water depends on the distribution of shoots at, or near, ground level. Thus shading directly affects that aspect of Vetiver growth which is most important for its effectiveness in controlling erosion.

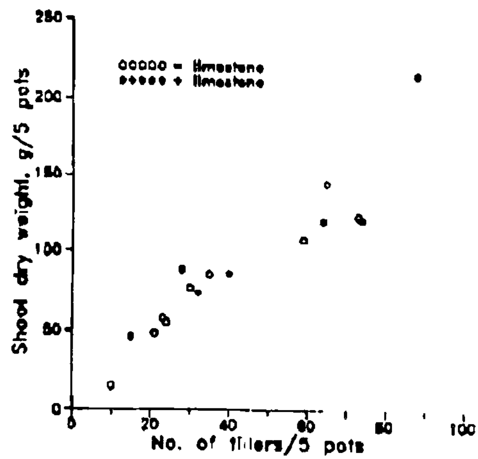

Fig. 3. Relation between Vetiver shoot dry weight and number of tillers.

It appears that the shade cast by bananas planted in standard arrangements is unsuitable for vigorous growth of Vetiver. We are left with two options: find clones of Vetiver (or other non-seeding grasses with vigorous tillering habits) which are less sensitive to shade, or manipulate the planting pattern of bananas to allow the Vetiver clone we have to grow vigorously. Attempts are being made to find and test other Vetiver clones for shade tolerance. Apparently, such material is available in Thailand (Disnada Diskul, pers. comm.). However, modifying banana spacings on each side of a grass line appears to be possible without reducing overall population densities or banana yields. Sample configurations are shown in Figure 4 for two commonly-used planting arrangements. Both modifications result in minor "local" overcrowding but early observations and results suggest that there are no harmful effects on the bananas and that the extra light available to the Vetiver is enough to allow vigorous growth.

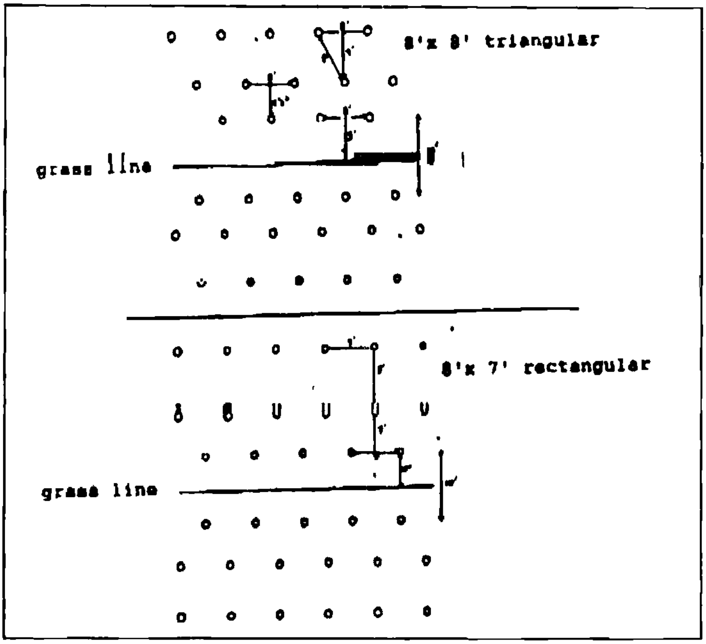

Fig. 4. Modified planting geometry for bananas to allow establishment of Vetiver grass lines.

The space taken up by the grass line is not a problem if the traditional method of planting Vetiver is modified. In the WI bunches of 'slips' ie. tillers have always been planted about 30-50 cm apart. This results in large clumps of the grass with wide gaps between the clumps. In order to achieve a useful barrier to surface-flow several lines, with clumps overlapped, are needed. This results in a wide grassline which takes up a lot of space. WINBAN has developed a system in which two or three tillers are planted 5-10 cm apart which results in a single, but effective, line without large gaps.

CONCLUSIONS

The technologies described above are simple and cheap to use. Covering the soil surface with banana trash protects the soil from erosion and helps to maintain, directly and indirectly through the promotion of earthworm activity, soil structure and fertility. Establishment and maintenance of Vetiver lines also reduces erosion and promotes infiltration of rainwater, which might have important consequences for production in lowland areas during the dry season although this is not yet proven.

Yet there are problems. On steep hillsides trash is quickly moved downslope by runoff and farmers usually pile it up, saying that it interferes with the application of chemicals if it is spread out and that it clogs drains. Farmers are also reluctant to introduce grasslines as it interferes with workers' movement up and down slopes. It also harbours rats, they say, and anyway it's a grass and grasses are weeds.

The real problem is that, although people pay lip-service to the notion that combating erosion is a good idea, the consequences of not doing so are too far in the future. We, as scientists, must demonstrate more tangible benefits from land management practices such as these if we are to see them adopted.

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