

# **Investigations into Soil Productivity Decline in the Irrigated Clarendon Plains**

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## **Abstract**

Comparisons were made of soil chemical, physical and biological properties between sugar cane lands in continuous production and lands in fallow for varying number of years on the irrigated plains of Clarendon.

At Morelands, significant improvements in organic matter, nitrogen, phosphorus, potassium, pH and salinity were detected in fallow lands compared to lands in continuous production. Fallow lands at New Yarmouth contained higher phosphorus, potassium and exhibited lower bulk density, sodium adsorption ratio, as well as lower cadmium and arsenic contents. In fallow lands at Springfield, all measured parameters, with the exception of organic matter which was significantly higher, were statistically similar to measurements in the continuously cropped plot. In general, fallowing in the irrigated plains appears to improve soil properties beneficial to cane productivity.

**Keywords:** Soil productivity, fallowing, soil chemical & physical properties, nematodes

## INTRODUCTION

Prolonged sugar cane monoculture is considered to impact soil productivity negatively as a result of nutrient and organic matter depletion, adverse changes in soil pH, soil compaction and build up of pests and diseases. Research conducted in South Africa (Meyer et al, 2001) pointed to degradation in chemical, physical and biological soil properties as a result of long term sugar cane monoculture. Workers in Australia (Bell et al, 2001, Garcide et al, 2005) have reported improved soil quality and yields with breaks in monoculture, trash blanket retention, reduced tillage as well as fumigation for nematode control. Long term field mechanization (Bell et al, 2001) resulted in the development of hard pan, high bulk density, low water infiltration rates and reduced irrigation efficiency.

Thresholds have been long established for the various nutrients for optimum productivity on Jamaican soils (Fearon, 2005; Anon., 1993).

The presence of heavy metals - cadmium (Cd) lead (Pb) and arsenic (As) in soils has been of some concern, mainly from an environmental stand-point, but the levels at which these are toxic to sugarcane were not established. Cadmium is an impurity in phosphorus fertilizers and arsenic is a constituent of the herbicide Daconate, which was used locally up to the late 1980s.

In 2004, the Sugar Industry Research Institute of Jamaica, under a project funded by the Common Fund for Commodities (CFC), initiated studies involving crop rotation and its effects in boosting cane yields (Anon., 2004). Ongoing trials conducted in irrigated and rain-fed areas of the Industry show promise.

The yield decline experienced in the Clarendon plains since 1971, Fig. 1a & 1b, has brought into focus the challenges to attain profitable cane production in that zone.

This study was therefore undertaken to compare soil chemical, physical and biological properties of lands in continuous sugar cane production with lands in fallow in order to isolate factors that may be associated with the observed yield decline.

Fig 1a. Production History for Estate A

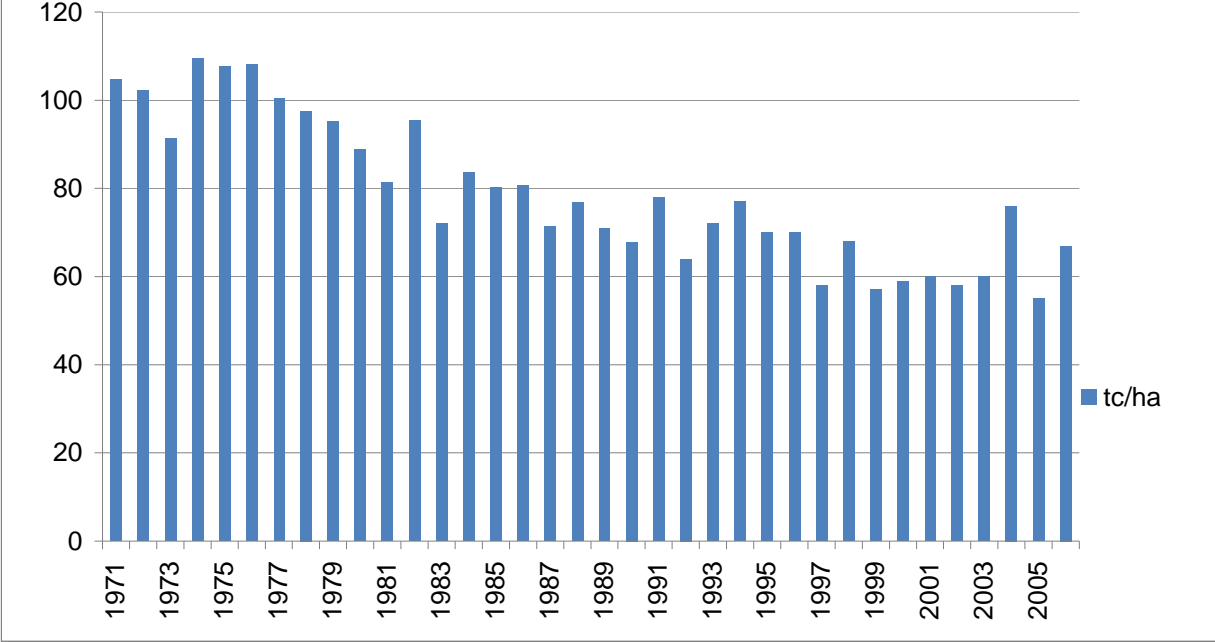
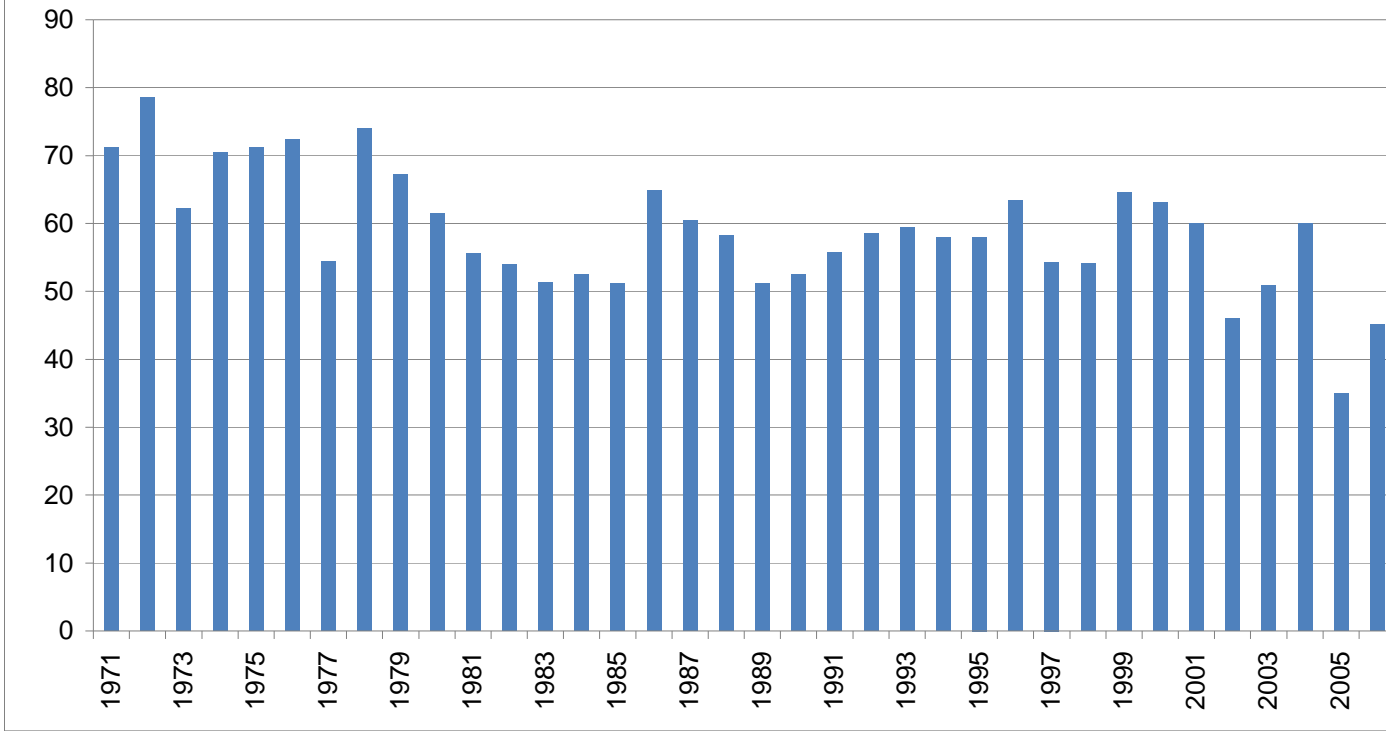


Fig 1b. Production History for Estate B



## METHOD

In January 2007, “paired sites” were selected at New Yarmouth, Farm 2 North (Site 1) where a plot in continuous cane production was found adjacent to an area in fallow for 10 years. At Monymusk, Springfield farm (Site 2), a site in continuous production was next to one in fallow for 15 years. Site 3, also at Monymusk (Morelands farm), paired a site in continuous production with one lying fallow for over 30 years.

The soils identified at the sites were Rhymesbury Clay at New Yarmouth, Agualta Clay at Springfield and Agualta Clay Loam at Morelands. Fallow areas of Sites 1 and 2 were in ruinate while Site 3 was partially occupied by fruit trees.

Six randomly placed mini soil pits were dug in both fallow and continuously farmed plots from which vertical soil core samples were taken during opening of the pits at depths of 0-15, 15-30 and 30-45 cm, referred to in the study as top, middle and bottom layers. In addition, soil samples were taken and prepared according to standard laboratory procedures for organic matter, nitrogen, phosphorus, potassium, sodium, sodium adsorption ratio and textural classification. Samples were also subjected to bulk density and water infiltration evaluations.

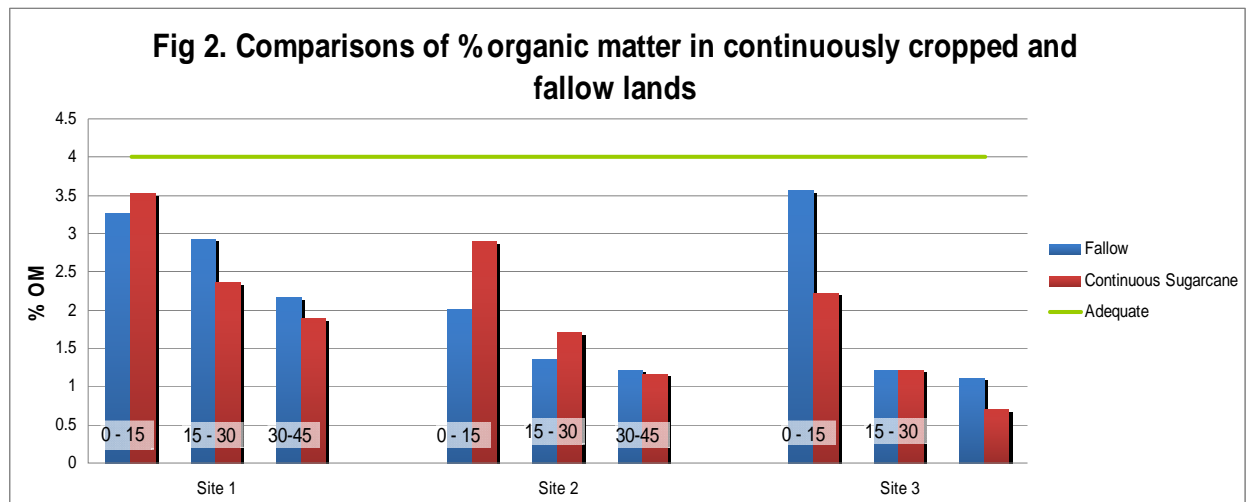
For nematode population studies, additional soil samples were later taken randomly at 0-15 cm depth at six locations in each plot. Special effort was made to include both soil and roots in plots so that nematode populations could be determined per 100ml of soil and per 100 grams of roots. These samples were also subjected to determinations for the heavy metals - As, Pb and Cd.

Statistical analyses were conducted using the paired t- test procedure.

## RESULTS AND DISCUSSIONS

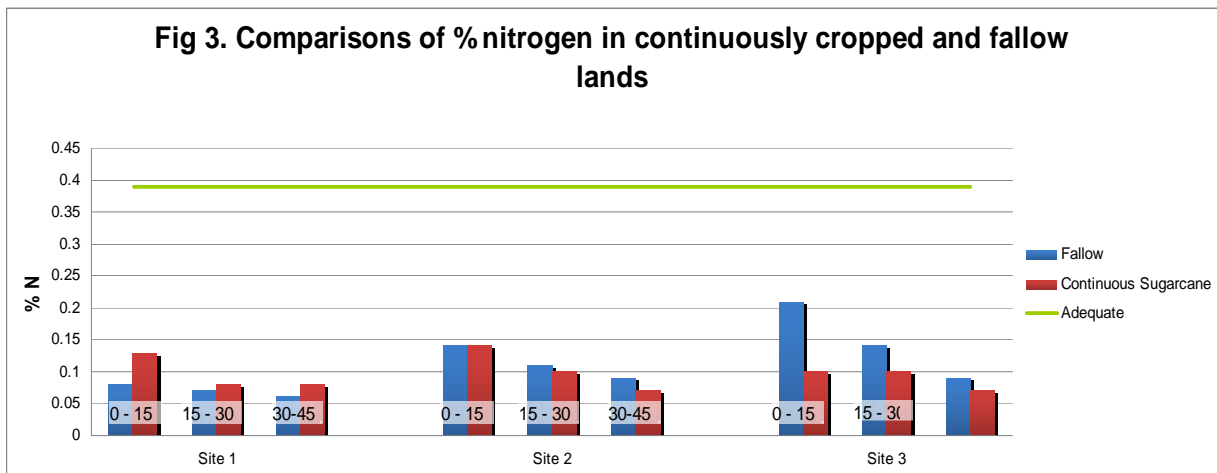
### Organic Matter

Though all sites were relatively low (below 4%) in organic matter, higher levels were found in the top soil of fallow lands at Springfield and Morelands, Fig. 2. There were no significant differences in organic matter at middle and bottom soil layers at all sites - a finding which was not surprising given the generally low organic matter usually found in sub-soil. Fallow fields at Sites 1 and 2 in particular were known to be occasionally accidentally burnt during pre-harvest burning of adjacent fields. This would have resulted in loss of organic matter being built-up during fallowing.



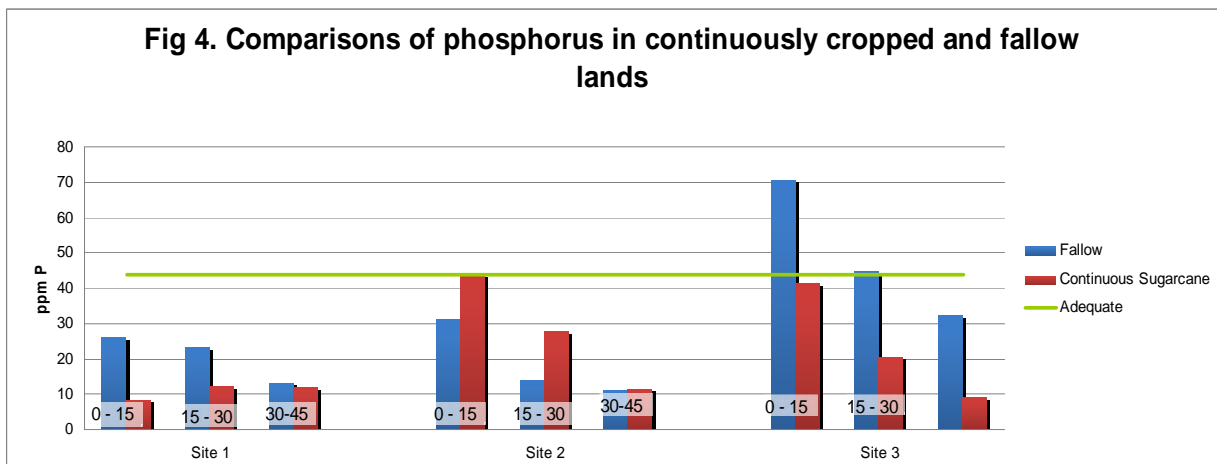
### Nitrogen

Nitrogen reserves were appreciably higher in the top and middle layers in fallow lands at Morelands compared to levels in the continuously cropped area, **Fig. 3**. However, lands in cane at New Yarmouth had higher % nitrogen which may have been a result of residual fertilizer from earlier application to the field. Nitrogen levels were low at all sites in keeping with the generally low reserves typical of local soils.



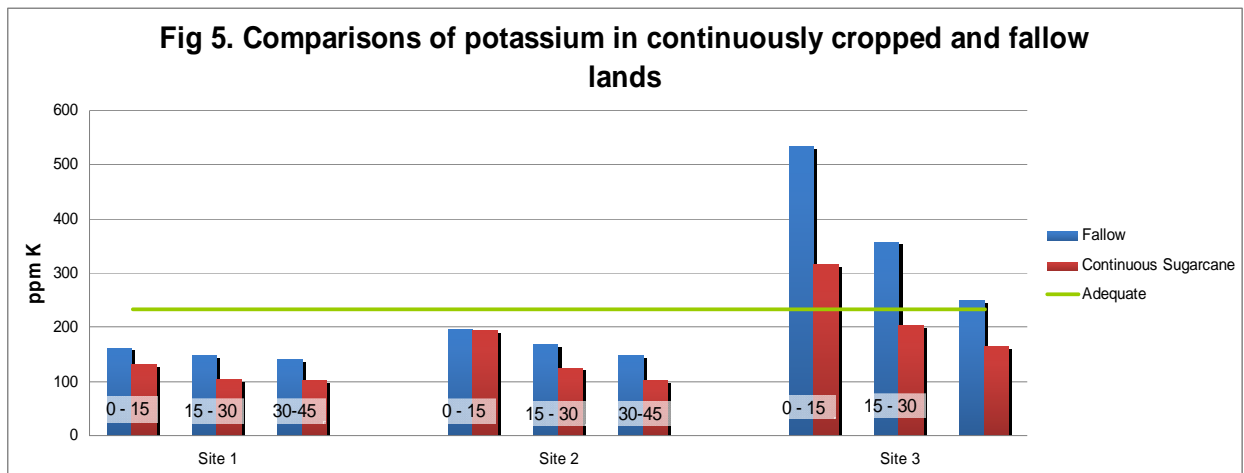
### Phosphorus

In the top layer of the fallow site at New Yarmouth (Site 1) higher levels of phosphorus (26 ppm) were found than in the continuously cropped area (8 ppm), ( $p < 0.05$ ), **Fig. 4**. However, P contents in the middle and bottom layers were statistically similar. At Morelands, phosphorus contents were higher in fallow plots at all three soil depths while at Springfield (Site 2) differences were not statistically significant.



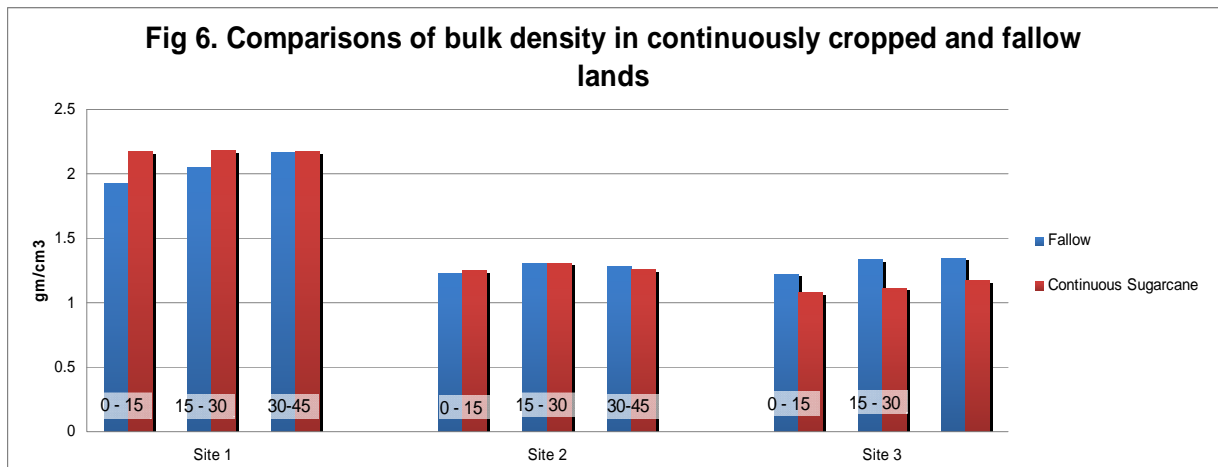
### Potassium

At Morelands, higher potassium contents ( $p < .05$ ) were observed at all sampling depths in fallow lands (Site 3) compared to cultivated areas, **Fig. 5**. At Site 2, potassium contents in fallow and cultivated lands were similar in the surface layer. In the lower layers potassium contents were higher in fallowed lands. At New Yarmouth (Site 1) significantly higher K contents were found in the fallow area at each depth.



### Bulk Density

At Site 1, bulk density, a measure of soil compaction, was significantly lower in the top layer of land in fallow (1.92 g/cm) than in the cultivated area (2.17 g/cm), **Fig 6**. Site 2 showed no significant bulk density differences between the areas compared while at Site 3 the surprising result was that bulk densities were actually better in the continuously cropped area. The latter result may have been due to the relatively recently conducted land preparation in fields which were first – fourth ratoons and possibly incorporation of organic matter during land preparation. In general the bulk densities at this site were less than 1.4 g/cm which was more favourable for crop growth.

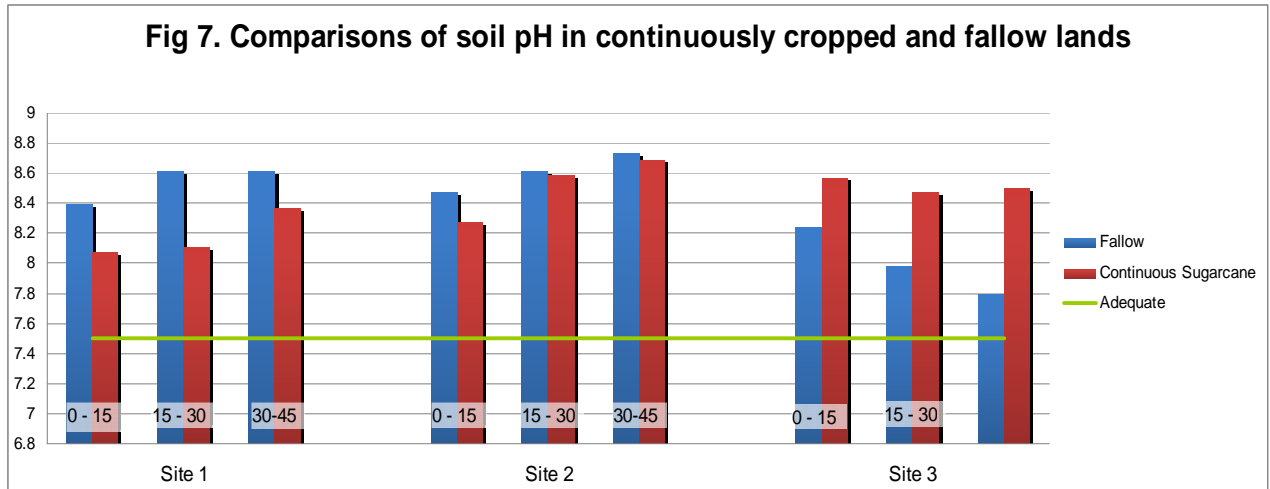


### Water Infiltration

With the sites being all relatively heavy clays, the infiltration rates in both fallow and cultivated lands were very slow (< 0.125 cm/hr) and not significantly different ( $p > 0.05$ ).

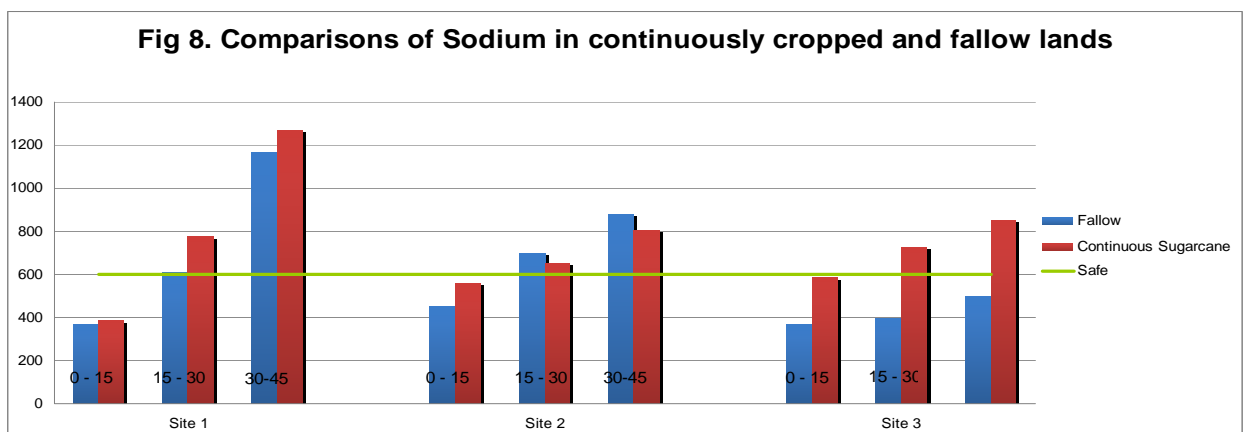
## Soil pH

Soil pH (8.11-8.73) was alkaline to highly alkaline and not statistically different in cultivated and fallow areas at Sites 1 & 2, **Fig. 7**. At Site 3, there was a tendency towards lower pH with increasing depth. For the most part, soils at test sites proved to be generally alkaline to very alkaline and would be considered limiting to cane growth.



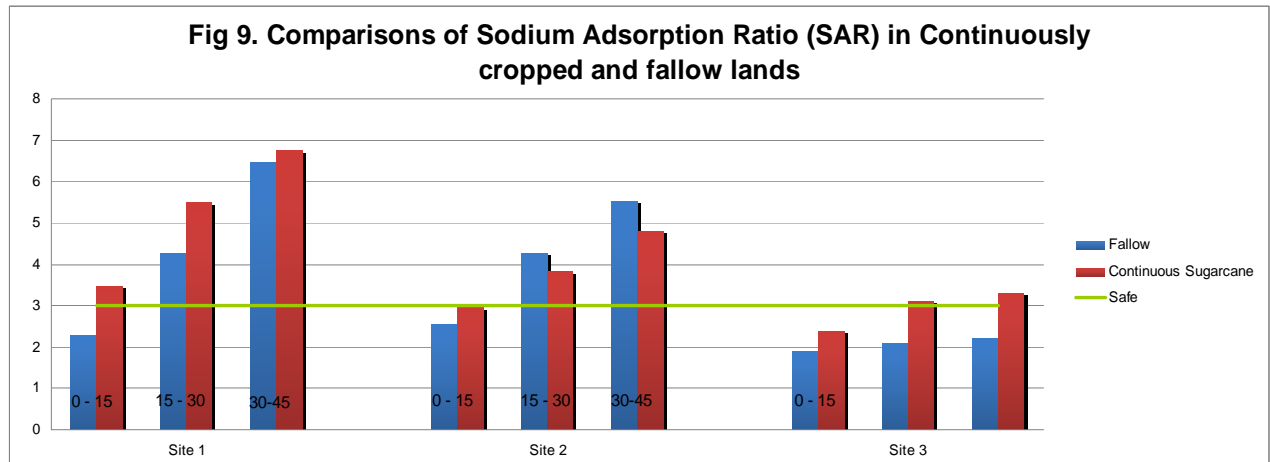
## Sodium

There was a tendency towards lower levels of sodium in fallow lands than in adjacent continuously cropped areas at Sites 1 and 3 but a reversal (not statistically significant) was observed at Site 2 in the subsoil layers **Fig. 8**. Lowest sodium levels tended to be found at Site 3 in fallow lands. Also, at this site where fallowing was longest, there tended to be a wider difference in sodium levels between cultivated and fallow areas.



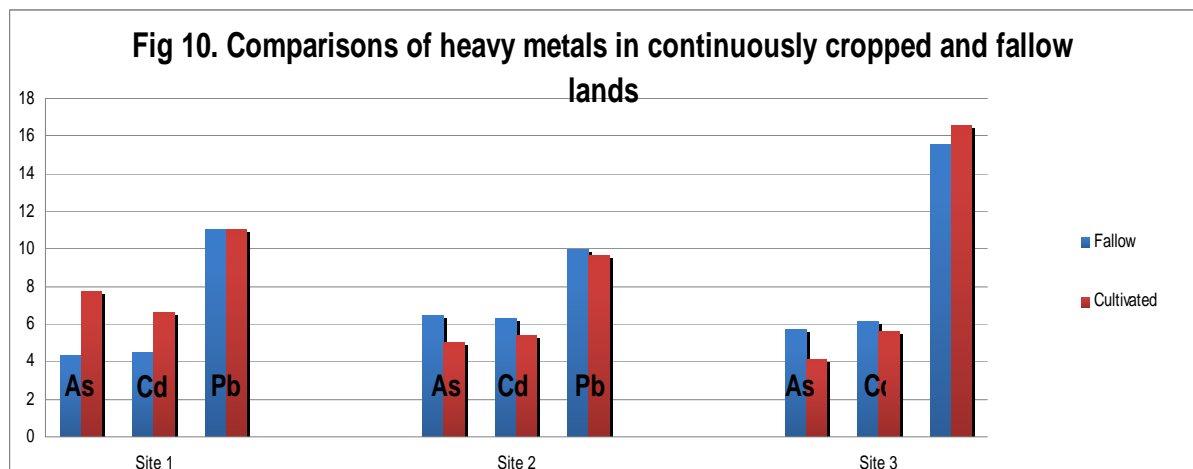
### Sodium Adsorption Ratio (SAR)

Sodium adsorption ratios - a measure of soil salinity – increased with soil depths, **Fig. 9**. At Site 2, SAR values were not statistically different for fallow and cultivated lands but Site 3 showed much more acceptable SAR levels in both fallow and cultivated lands. The results suggest that prolonged use of irrigation water (known to be of relatively poor quality) may be increasing soil salinity.



### Heavy Metals

At Site 1, the arsenic concentration in fallow land (4.36 ppm) was significantly lower than in cultivated land (7.78 ppm), **Fig. 10**. Arsenic at Sites 2 and 3 was statistically similar for fallow and cultivated areas. Cadmium was also statistically lower in fallow lands (4.5ppm, Site 1), than in cultivated lands (6.63 ppm) but differences were less evident at Sites 2 and 3. There were no significant differences in lead concentrations at the various sites although Site 3 stood out with higher concentration.



According to Kwong et al (2005), sugarcane exhibits relatively low uptake of cadmium and lead and the low concentrations found suggest very little potential harm even from an environmental safety standpoint. Levels of arsenic, cadmium and lead below 41, 19 and 190 ppm, respectively, are usually considered environmentally safe.

### Nematode populations

Nematode species, *Helicotylenchus*, *Pratylenchus*, *Paratylenchus*, *Melioidogyne*, *Rotylenchulus reneformis* were identified at the study sites but populations in fallow and cultivated lands were not statistically different, **Table 1**. *Pratylenchus*, considered the most damaging nematode to sugar cane world wide, was found at levels in the vicinity of 200/ml soil, or much below the thousands/ml recorded where nematodes are considered at damaging levels (Cadet & Vaughn 1985). *Helicotylenchus* populations were also not significantly different in the soils compared. Similarly, levels of nematodes found per gram of root, **Table 2**, were well within safe limits.

<b>Table 1. Comparisons of mean nematode population per 100 ml soil in continuously cropped and fallow lands</b>					
<b>Site 1</b>		<b>Site 2</b>		<b>Site 3</b>	
<b>Fallow</b>	<b>Continuously Cultivated</b>	<b>Fallow</b>	<b>Continuously Cultivated</b>	<b>Fallow</b>	<b>Continuously Cultivated</b>
<i>Helicotylenchus sp.</i>					
81	293	13	41	15	16
<i>Pratylenchus sp.</i>					
65	39	17	11	205	28
<i>Paratylenchus sp.</i>					
0	0	0	0	226	0
<i>Melioidogyne sp.</i>					
0	0	0	0	140	0
<i>Rotylenchulus reneformis sp.</i>					
0	0	0	0	0	16

<b>Table 2. Comparisons of mean nematode population per 100 grams roots in continuously cropped and fallow lands</b>					
<b>Site 1</b>		<b>Site 2</b>		<b>Site 3</b>	
<b>Fallow</b>	<b>Continuously Cultivated</b>	<b>Fallow</b>	<b>Continuously Cultivated</b>	<b>Fallow</b>	<b>Continuously Cultivated</b>
<i>Helicotylenchus sp.</i>					
0	234	0	0	0	0
<i>Pratylenchus sp.</i>					
0	186	0	0	0	0
<i>Paratylenchus sp.</i>					
0	0	0	0	0	9

## CONCLUSIONS

Comparisons of soils under continuous cane cropping and similar soils kept in fallow showed that higher levels of organic matter, phosphorus and potassium occurred in the fallowed areas.

Heavy metals accumulated with continuous sugar cane cropping but were not considered to be at dangerous levels. However, further investigations are needed to determine levels which may be sufficiently toxic to inhibit cane yields.

The nematodes, *Helicotylenchus*, *Pratylenchus*, *Paratylenchus* and *Meliodogyne*, considered harmful to sugarcane, were found at levels considered well below their respective economic damage thresholds.

Lower sodium and sodium adsorption ratios in fallowed areas may be attributed to the discontinuation of irrigation which would have brought on added salts. The high salinity in sub-soils at New Yarmouth and Springfield in fallowed and cultivated areas calls attention to the quality of irrigation water used, quantities applied and the quality of drainage on these heavy clays.

A fallow period for sugar cane lands in the irrigated Clarendon plains appears beneficial for improving soil chemical properties. However, prospects for fallowing are limited by the factory's demand for and relatively low supply of cane in the area. An alternative measure for improving productivity could be a programme of soil amendments through addition of filter cake, distillers waste and poultry manure as well as conducting general improvements in soil management and drainage.

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