

THE SULPHUR DEPOSITION BY RAINFALL IN SOME AGRICULTURALLY IMPORTANT AREAS OF SRI LANKA

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ABSTRACT

Rainwater samples were collected from ten agriculturally important areas of Sri Lanka for a period of one year and their sulphate sulphur contents were determined turbidimetrically. The quantities deposited by rain ranged from 23.9 kg S/ha at Bombuwela to 4.9 kg S/ha at Murunkan. Locations receiving high rainfall generally had higher sulphur deposition than those receiving low rainfall.

Comparison of sulphur content of rainwater with that of irrigation water showed that the quantity of sulphur brought by irrigation water to a rice crop was much higher than that supplied by rain.

With the decline in the use of ammonium sulphate in Sri Lanka the amount of S in the components of the S cycle may show a corresponding decrease, thereby perhaps altering the future picture of the S needs of crops.

INTRODUCTION

Sulphur is an essential nutrient which is removed by plants in about the same quantities as phosphorus, yet not much attention has been paid in the past to sulphur requirements of crops. This is perhaps due to the fact that contribution from natural sources and from some agrochemicals may have been sufficient to meet the sulphur requirements of most crops.

During the last decade Sri Lankan farmers, especially those in the annual crop sector, have used urea and triple superphosphate almost exclusively as the sources of N and P, thereby reducing significantly the entry of S into the fields in comparison to the earlier use of ammonium sulphate and single superphosphate. Further, most pesticides in use today have little or no S compared to those used in the past.

Crop yields have shown an upward trend in recent times and so has cropping intensity with the provision of increased irrigation facilities. Thus more S is removed per unit area of land per year than before, at a time when less S is entering the fields in the form of agrochemicals. A combination of these factors may have led to the recent appearance of S deficiencies in many countries. Yield increases of crops to addition of S have been reported in Philippines (Lockard *et al*, 1972), Nigeria (Osiname *et al*, 1975), Bangladesh (Anon. 1978), Indonesia (Blair *et al*, 1979) and Sri Lanka (Lathif *et al*. 1981).

Plants can obtain their S requirements from soil, irrigation water, rainfall and the atmosphere. Of these only the S content of the waters from some of the large irrigation reservoirs in Sri Lanka has been determined (Amarasiri, 1973). This paper reports on the sulphur content in the rainwater collected from ten agriculturally important areas in Sri Lanka.

MATERIALS AND METHODS

The rainwater was collected in the rain gauges ordinarily used to measure rainfall at the Agricultural Research Stations at Bandarawela, Batalagoda, Bombuwela, Gannoruwa, Karadian Aru, Maha Illuppallama, Murunkan, Paranthan and Sita Eliya, and at the Department of Agriculture Farm at Malwatta, Amparai. The sampling locations are shown in Figure 1.

After the volume of rain was read off to determine the rainfall during the preceding 24 hours, all the water was transferred into a plastic container. A few drops of chloroform were added to prevent microbial growth. A sub sample of the month's collection of rainwater was brought at the end of each calendar month to the laboratories of the Central Agricultural Research Institute, Gannoruwa, for analysis.

The water was filtered through a Whatman No 42 filter paper. A sample was then placed on a heated water bath and evaporated until its volume was reduced sixfold. Ten ml of the concentrated sample was transferred to a 100 ml conical flask. One ml of 8N HNO₃ containing 20 ppm S as K₂SO₄ (acid seed solution) was then added followed by 0.5 g BaCl₂ crystals (30-60 mesh). The flask was swirled until the BaCl₂ dissolved and then stirred with a magnetic stirrer for one minute. The contents were transferred to a spectrophotometer curvette, allowed to stand for 5 minutes and the turbidity read at 420 nm. The concentration of S was determined from a standard curve obtained with solutions of K₂SO₄ ranging from 3 to 20 ppm S.

Although only the sulphate sulphur in the rainwater has been determined, this is being referred to as S in the text for simplicity. However, almost all the sulphur in the rainwater is expected to be in the sulphate form.

This study commenced in May 1980 at Gannoruwa and in September 1980 at the other locations, and was continued for 12 months at each location.

RESULTS AND DISCUSSION

The atmosphere has many sulphur containing gases. Some of these are sulphur dioxide, hydrogen sulphide, carbonyl sulphide and methyl mercaptan. Sulphur dioxide is the one which is by far the most abundant and the most stable. It is produced by the burning of fuel oils, in smelting processes, from volcanic activity and from atmospheric oxidation of hydrogen sulphide and other gases produced by anaerobic decomposition of organic materials.

SULPHUR DEPOSITION OF RAINFALL IN SRI LANKA

Sulphur dioxide can be absorbed by soil (Jones *et al.* 1979), vegetation (Fried, 1949) and water. Owing to its very high solubility in water it can be readily absorbed by oceans, rivers, lakes, irrigation reservoirs and other open water bodies. For the same reason rain drops as they form and fall down have the opportunity to dissolve the sulphur dioxide with which they come into contact.

The monthly distribution of sulphur brought down by rain at ten locations in Sri Lanka is given in Table 1. The highest annual deposition is at Bombuwela with a value of 23.9 kg/ha and the lowest is at Murunkan with a value of 4.9 kg/ha. The rainfall during the period of study and the ten year average (1971-1980) for the locations are shown in Table 2. With a few exceptions locations receiving higher rainfall have greater depositions of sulphur. For any given location the S content brought down by rain is lower in the six dry months than in the six wet months (Table 3). This is especially so for the dry zone. The difference between the two periods is small in the wet zone which has a well distributed pattern of rainfall. Amparai is an exception to this observation.

Of the 120 values reported for monthly sulphur deposition given in Table 1, the figures for Karadian Aru in July and for Batalagoda in November are unusually high. Karadian Aru received 267 mm rain in July which is about 8 times the ten year average for the month. The high S value is probably related to this unusual rain. As far as Batalagoda is concerned, November was its wettest month and the amount of rain was higher than the ten year average for the month, but not markedly different from it as in the previous example in order to explain the high value of 6.4 kg/ha.

The rainfall during the period of study has been lower for most locations than the long term average. It is therefore likely that the annual S deposition in most years would be somewhat greater than that reported here for many of the locations, other factors being the same.

Sea spray contains sulphate sulphur. The movement of this source inland will depend on wind activity and rainfall. While the gaseous SO₂ can be transported over hundreds of kilometres in the atmosphere, there is evidence that the sulphate in the sea spray travels through only relatively short distances (Hutton *et al.* 1958). Of the locations studied Amparai, Bombuwela, Karadian Aru, Murunkan and Paranthan are close to the sea. Bombuwela and Murunkan are unlikely to receive much sulphur from sea spray during the Maha season because the sea is to their west, while the winds are coming from the northeast. Bombuwela however may get the effect of the spray during the southwest monsoon.

The high value for S at Bombuwela may be due to the high rainfall, close proximity to the ocean, presence of rice fields and water bodies under reduced conditions in the region and due to an industrial activity 3 km away burning about two hundred thousand litres of furnace oil a month.

The sulphur deposited by rain annually at the ten locations reported here is much lower than that reported for some industrial areas of the world (Table 4), but higher than the values reported for the rainfall in Central Kenya (Broomfield *et al.*, 1980).

The sulphur needs of crops can be met by the soil, irrigation water, rainwater and from SO₂ in the atmosphere. The atmospheric sulphur dioxide content in different parts of Sri Lanka has not been reported. The amount of sulphur removed by a few crops is given in Table 5. Of these the quantity removed by rubber is comparatively small. The sulphur deposited by rain in the wet zone areas where this crop is grown may help significantly to meet its requirements. For rice cultivated in the dry zone the estimated contribution from rainwater and from irrigation water are given in Table 6 assuming that half the annual precipitation of S is available for the crop and assuming a duty of 1.22 hectare metres of irrigation water per crop (Murakami, T. 1966 Unpublished). The rainwater contribution of S is small compared with that from irrigation water. Amparai is likely to be an area where sulphur deficiencies may arise in the future. This is because the irrigation water and rainwater S are low, some of the soils are coarse textured and low in organic matter content and also because intensive cropping is practised owing to availability of irrigation. Paranthan too may face a sulphur problem for similar reasons.

The sulphur needs of rainfed intensive vegetable farming in Bandarawela, Nuwara Eliya and Welimada also merit consideration. Cruciferous crops containing relatively high amounts of S are grown here, and very high yields are often obtained. Many of these crops are unirrigated and therefore do not benefit from the S content of irrigation water. The effects of additions of S to these crops need to be studied. The sulphur requirements of rainfed crops of maize, chillies, groundnut and soybean should also be worked out. Such studies are important to determine whether S may limit the attainment of high yields.

Ammonium sulphate and petroleum products are two sulphur containing items imported to Sri Lanka which can ultimately increase the sulphur content of the components of the sulphur cycle. The amounts of S contained in these two sources are shown in Figure 2. It is seen that in 1970 the S content of imported ammonium sulphate was more than three times that in the petroleum products. But during the last few years ammonium sulphate use has decreased steadily. Its use is expected to go down much further since, as opposed to earlier times, the current price of a unit of nitrogen in ammonium sulphate is more than four times that in urea. The increase in use of petroleum products in the near future is not likely to be of such magnitude so as to offset the reduction in import of sulphate of ammonia as far as the entry of S into Sri Lanka is concerned. This is expected to have a downward effect on the sulphur content of soil, atmosphere, irrigation water and rainfall, showing the need to be watchful in regard to the future sulphur needs of Sri Lankan agriculture.

SULPHUR DEPOSITION OF RAINFALL IN SRI LANKA

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Table 1—Sulphur brought down by rainfall at different locations in Sri Lanka (kg/ha).

| <i>Location</i> | <i>January</i> | <i>February</i> | <i>March</i> | <i>April</i> | <i>May</i> | <i>June</i> | <i>July</i> | <i>August</i> | <i>Sept.</i> | <i>October</i> | <i>Nov.</i> | <i>Dec.</i> | <i>Total</i> |
|-------------------|----------------|-----------------|--------------|--------------|------------|-------------|-------------|---------------|--------------|----------------|-------------|-------------|--------------|
| Amparai | 0.6 | 1.3 | 1.4 | 1.3 | 0.0 | N.R. | 0.7 | 0.1 | 2.2 | 1.1 | 1.3 | 0.8 | 10.8 |
| Bandarawela | 0.2 | 0.5 | 0.9 | 0.7 | 0.4 | 0.2 | 1.4 | 0.4 | 1.6 | 1.3 | 0.9 | 0.4 | 8.9 |
| Batalagoda | 0.3 | 0.1 | 2.0 | 1.4 | 0.8 | 0.9 | 0.6 | 0.2 | 1.1 | 2.1 | 6.4 | 1.4 | 17.3 |
| Bombuwela | 0.5 | 0.4 | 2.9 | 3.5 | 3.8 | 1.9 | 0.9 | 1.8 | 1.5 | 2.2 | 1.1 | 3.4 | 23.9 |
| Gannoruwa | N.R. | N.R. | 1.0 | 1.4 | 1.0 | 2.0 | 1.4 | 1.2 | 1.3 | 1.5 | 1.7 | 0.8 | 13.3 |
| Karadian Aru | 0.5 | 0.7 | 0.5 | 0.6 | 0.4 | 0.2 | 6.0 | 0.2 | 1.8 | 1.2 | 1.4 | 1.1 | 14.6 |
| Maha Illuppallama | 0.0 | N.R. | 0.4 | 1.6 | 0.5 | 0.1 | 0.8 | 0.2 | 1.2 | 0.9 | 0.7 | 0.6 | 7.0 |
| Murunkan | 0.2 | N.R. | N.R. | 0.4 | 0.7 | 0.2 | 0.3 | N.R. | 0.4 | 0.5 | 1.1 | 1.1 | 4.9 |
| Paranthan | 0.2 | 0.6 | 0.3 | 0.4 | 1.2 | N.R. | 2.0 | N.R. | 2.0 | 1.9 | 2.3 | 0.4 | 11.3 |
| Sita Eliya | N.R. | 2.2 | 0.9 | 0.5 | 0.8 | 1.2 | 1.7 | 0.9 | 2.1 | 1.2 | 0.9 | 0.3 | 12.7 |

N.R. = No Rain

SULPHUR DEPOSITION OF RAINFALL IN SRI LANKA

Table 2—Monthly rainfall (m m) during period of study and the ten-year average of sampling sites*

| Location | J | F | M | A | M | J | J | A | S | O | N | D | Total |
|--------------------------|------------|-----------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|-------------|
| Amparai | 142 | 113 | 58 | 110 | 9 | 0 | 198 | 11 | 155 | 142 | 153 | 203 | 1304 |
| <i>Amparai</i> | <i>127</i> | <i>59</i> | <i>74</i> | <i>62</i> | <i>102</i> | <i>23</i> | <i>42</i> | <i>38</i> | <i>99</i> | <i>179</i> | <i>280</i> | <i>398</i> | <i>1485</i> |
| Bandarawela | 41 | 64 | 66 | 180 | 112 | 30 | 119 | 36 | 150 | 173 | 329 | 93 | 1472 |
| <i>Diyatalawa</i> | <i>71</i> | <i>74</i> | <i>99</i> | <i>173</i> | <i>103</i> | <i>51</i> | <i>51</i> | <i>58</i> | <i>153</i> | <i>273</i> | <i>247</i> | <i>199</i> | <i>1552</i> |
| Batalagoda | 95 | 9 | 96 | 199 | 135 | 107 | 54 | 72 | 190 | 345 | 473 | 122 | 1897 |
| <i>Kurunegala</i> | <i>22</i> | <i>92</i> | <i>122</i> | <i>279</i> | <i>208</i> | <i>156</i> | <i>108</i> | <i>121</i> | <i>154</i> | <i>363</i> | <i>346</i> | <i>157</i> | <i>2128</i> |
| Bombuwela | 98 | 17 | 153 | 436 | 475 | 389 | 70 | 96 | 404 | 553 | 264 | 233 | 3188 |
| <i>Bombuwela</i> | <i>22</i> | <i>73</i> | <i>113</i> | <i>467</i> | <i>383</i> | <i>271</i> | <i>152</i> | <i>111</i> | <i>266</i> | <i>489</i> | <i>393</i> | <i>195</i> | <i>3005</i> |
| Gannoruwa | 0 | 0 | 92 | 122 | 156 | 133 | 127 | 105 | 120 | 210 | 286 | 76 | 1427 |
| <i>Kandy</i> | <i>39</i> | <i>43</i> | <i>65</i> | <i>197</i> | <i>178</i> | <i>121</i> | <i>130</i> | <i>119</i> | <i>167</i> | <i>275</i> | <i>327</i> | <i>192</i> | <i>1853</i> |
| Karadian Aru | 138 | 71 | 21 | 96 | 28 | 9 | 267 | 12 | 111 | 208 | 238 | 255 | 1454 |
| <i>Batticaloa</i> | <i>123</i> | <i>83</i> | <i>49</i> | <i>46</i> | <i>39</i> | <i>21</i> | <i>34</i> | <i>32</i> | <i>102</i> | <i>204</i> | <i>344</i> | <i>436</i> | <i>1513</i> |
| Maha Illuppallama | 57 | 11 | 42 | 192 | 81 | 7 | 91 | 47 | 192 | 179 | 423 | 156 | 1478 |
| <i>Maha Illuppallama</i> | <i>49</i> | <i>33</i> | <i>43</i> | <i>195</i> | <i>97</i> | <i>12</i> | <i>44</i> | <i>35</i> | <i>102</i> | <i>248</i> | <i>254</i> | <i>212</i> | <i>1324</i> |
| Murunkan | 20 | 0 | 0 | 73 | 91 | 40 | 18 | 0 | 44 | 178 | 172 | 93 | 729 |
| <i>Mannar</i> | <i>20</i> | <i>25</i> | <i>44</i> | <i>80</i> | <i>69</i> | <i>8</i> | <i>8</i> | <i>8</i> | <i>38</i> | <i>177</i> | <i>235</i> | <i>208</i> | <i>920</i> |
| Paranthan | 18 | 29 | 9 | 44 | 131 | 0 | 111 | 0 | 151 | 216 | 459 | 85 | 1253 |
| <i>Jaffna</i> | <i>28</i> | <i>23</i> | <i>20</i> | <i>32</i> | <i>57</i> | <i>20</i> | <i>23</i> | <i>26</i> | <i>52</i> | <i>280</i> | <i>266</i> | <i>314</i> | <i>1141</i> |
| Sita Eliya | 0 | 78 | 66 | 81 | 150 | 231 | 244 | 96 | 231 | 158 | 301 | 83 | 1719 |
| <i>Nuwara Eliya</i> | <i>67</i> | <i>50</i> | <i>44</i> | <i>153</i> | <i>186</i> | <i>160</i> | <i>196</i> | <i>185</i> | <i>188</i> | <i>258</i> | <i>232</i> | <i>211</i> | <i>1930</i> |

* Where ten-year averages are not available for a sampling site, the corresponding data from the nearest meteorological station are used. For example, data from Diyatalawa meteorological station are used to get an idea of the Bandarawela ten year average.

The ten year averages are given in italics.

Source: Department of Meteorology;
Land and Water Use Division;
Department of Agriculture.

Table 3—Amount of S in rainfall in the six driest months of the year

| <i>Location</i> | | | <i>Amount of S</i> kg/ha | <i>Percent of annual deposition</i> |
|---------------------------|-----|-----|-----------------------------|-------------------------------------|
| Dry Zone: | | | | |
| Amparai | ... | ... | 3.9 | 36 |
| Karadian Aru | ... | ... | 2.6 | 18 |
| Maha Illuppallama | ... | ... | 1.2 | 17 |
| Murunkan | ... | ... | 0.7 | 14 |
| Paranthan | ... | ... | 1.5 | 17 |
| Intermediate Zone: | | | | |
| Bandarawela | ... | ... | 2.6 | 29 |
| Batalagoda | ... | ... | 4.1 | 24 |
| Wet Zone: | | | | |
| Bombuwela | ... | ... | 9.9 | 41 |
| Gannoruwa | ... | ... | 4.1 | 38 |
| Sita Eliya | ... | ... | 4.8 | 38 |

Table 4—Amount of S in precipitation at various locations

| <i>Location</i> | | <i>Year</i> | <i>Amount of S</i> kg/ha/yr | <i>Reference</i> |
|----------------------------------|-----|-------------|--------------------------------|---------------------------|
| Britain—country av. | ... | 1977 | 70 | Mellanby (1977) |
| New Zealand—rural | ... | 1960 | 0.5–3 | Fried <i>et al</i> (1949) |
| Sweden—indust. | ... | 1954–57 | 46 | do. |
| United States of America: | | | | |
| Indiana—indust. | ... | 1946–47 | 140 | do. |
| Minnesota—indust. | ... | 1936 | 217 | Alway <i>et al</i> (1937) |
| —rural | ... | 1936 | 3 | do. |
| Wisconsin—indust. | ... | 1969–71 | 168 | Terman (1978) |
| —rural | ... | 1969–71 | 16 | do. |
| West Germany—indust. | ... | 1957–58 | 88 | Fried <i>et al</i> (1949) |
| —rural | ... | 1957–58 | 11–13 | do. |

SULPHUR DEPOSITION OF RAINFALL IN SRI LANKA

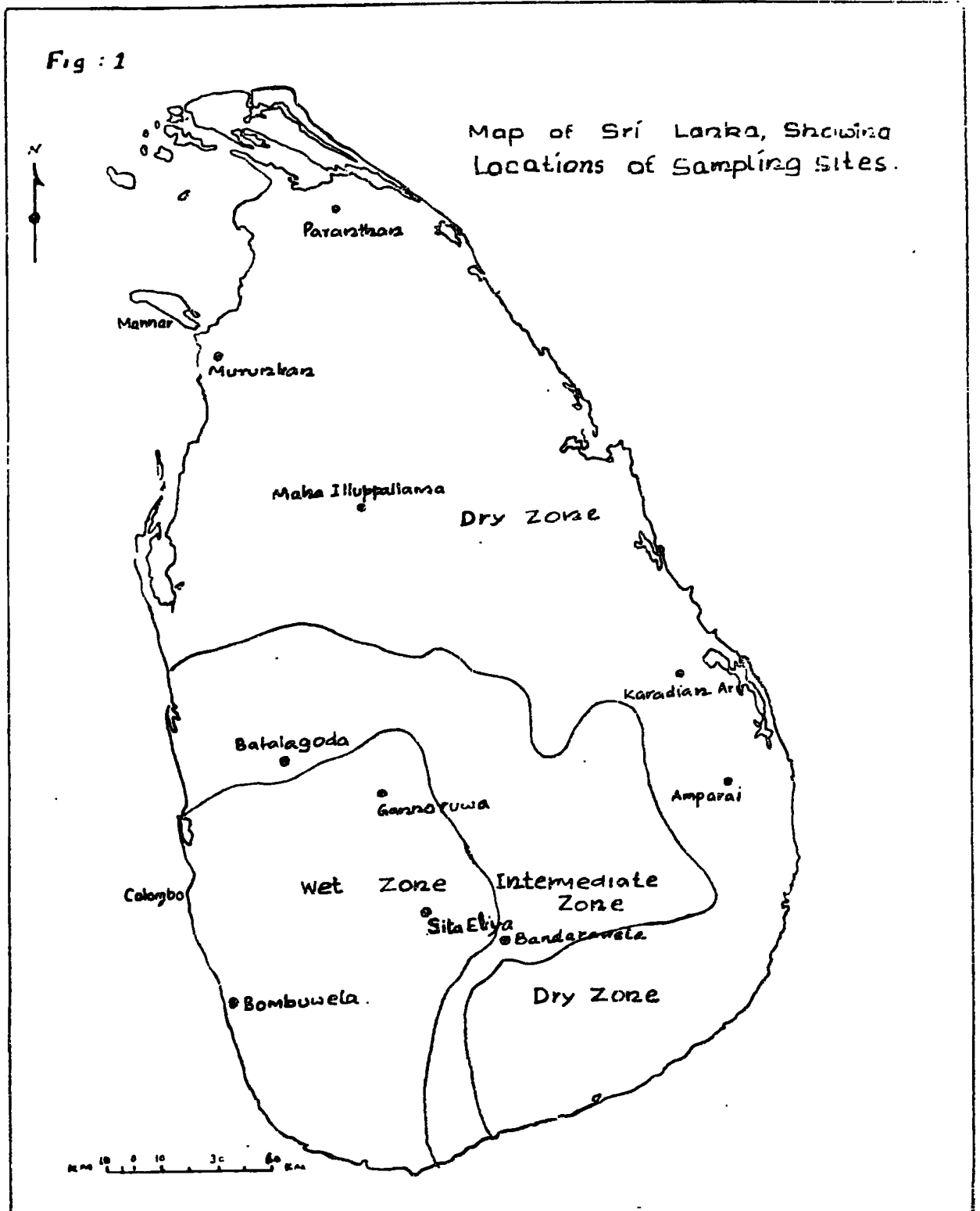
Table 5—Sulphur removal by crops

| <i>Crop</i> | | <i>Plant Part</i> | <i>Yield</i> | <i>Sulphur Re- moval</i> | <i>Reference</i> |
|-------------|-----|-------------------|--------------|------------------------------|-------------------------------|
| | | | kg/ha | kg/ha | |
| Cabbage | ... | tops | 15,000 | 19 | Bixby <i>et al</i> (1973) |
| Coconut | ... | nut | 7000 | 18 | De Geus (1973) |
| Cotton | ... | seed | 1900 | 19 | Amarasiri <i>et al</i> (1975) |
| Groundnut | ... | seed | 3360 | 28 | Beaton <i>et al</i> (1971) |
| Maize | ... | grain | 4000 | 13 | Amarasiri <i>et al</i> (1975) |
| Onion | ... | bulb | 15,000 | 18 | Bixby <i>et al</i> (1964) |
| Potato | ... | tuber | 27,000 | 30 | Beaton <i>et al</i> (1971) |
| Rice | ... | grain | 5000 | 9 | Amarasiri <i>et al</i> (1975) |
| Rubber | ... | latex | 3000 | 4 | De Geus (1978) |

Table 6—Estimation of S supply by irrigation water and rainfall

| <i>Location</i> | <i>Irrigation Source</i> | <i>Quantity of S</i> | |
|-------------------|--------------------------|--------------------------|-----------------|
| | | <i>Irrigation Water*</i> | <i>Rainfall</i> |
| kg/ha/season | | | |
| Amparai | Senanayake Samudraya | 14 | 5.4 |
| Karadian Aru | Rukam | 22 | 7.3 |
| Maha Illuppallama | Kalawewa | 22 | 3.5 |
| Murunkan | Giant's Tank | 43 | 2.5 |
| Paranthan | Iranamadu | 14 | 4.5 |

* Source: Amarasiri (1973).



SULPHUR DEPOSITION OF RAINFALL IN SRI LANKA

Fig : 2 The quantity of sulphur present in imported ammonium sulphate and petroleum products

