Using integrated plant nutrient management strategy for sustainable and competitive cocoa production in Ghana

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ABSTRACT

Cocoa production in Ghana is becoming less sustainable and less competitive because of several years of continuous low input cocoa cultivation that depends mainly on nutrient reserves of newly cleared forest thus resulting in the degradation of soil resource base. The necessity for external plant nutrient replenishment resulted in the introduction of recommended cocoa fertilizers like Asaase Wura, Cocofeed, Cocoa Master, Cocoa Sett, Sidalco liquid fertilizers, Nutrismart, Natural Asontem, poultry manure and cocoa pod husk ash as an initial solution to the fertility problem. For an efficient intervention to the existing problem, it is important to monitor the levels of degradation of cocoa soils in the different ecological zones and cropping systems. A study was therefore, conducted by sampling and analyzing eight hundred soil samples from the depths of 0-15 and 15-30 cm of different soil groups - Acrisols (75%), Lixisols (10%), Ferrasols (9%) and Nitisols (3%) of the Ghana cocoa belt, within five cocoa regions namely Eastern, Ashanti, Western North, Western South and Central Regions. Additionally, nutrient analyses of different parts of the cocoa plant were undertaken. Analyses of the parts of the crop indicated that nutrient losses through the beans which are exported needed to be replaced especially nitrogen (2.81%) which is the highest. The results also showed the need to increase the levels of the basal cations in these soils to enrich the base saturation of these soils. It could be noted from the fertilizers recommended for use in the country that, N and basal cations are lacking in some of the formulations whilst others have these elements. The paper concludes on the need to integrate the fertilizers that contains N and basal cations especially calcium to meet the standard ratio of K:Ca:Mg of 2:17:8 with those lacking these elements in order to increase the level of N and basal cations in the soil thereby increasing yields and also enriching the base saturation of the soil. Also for cocoa farmers to adopt the integrated application of all these tested fertilizers annually to ensure balanced nutrient supply for sustainable and competitive cocoa production from the Ghana cocoa belt.

INTRODUCTION

Cocoa is an important cash crop to the Ghanaian economy and its cultivation started in 1879. From the time when cocoa was introduced in Ghana, its cultivation exploit the residual fertility of newly cleared forest and long term cocoa cultivation with low input has led to soil nutrient depletion and land degradation (Ahenkorah *et. al*., 1981). Currently, there is little forest left to be exploited, so making cocoa cultivation a sustainable venture is a requirement for it to continue to play an important role in the economic development of Ghana.

Changes in land-use, resulting in deforestation, means that cocoa farms are less protected from environmental stress. Majority of cocoa farms in the cocoa growing regions in Ghana are very old and farmers are now migrating to new areas in the West, where incidentally, the soil conditions are considered unsuitable or marginally suitable for cocoa (Appiah *et al*., 1997). Basically, cocoa farmers are moving from one area to another grubbing the existing small forest left for cocoa production (High Technology Committee, 2002). Taking into account the importance of cocoa to the country's economy, a greater part of the existing cocoa-tree stocks have to be renewed. The implications of the soil fertility conditions, the depletion of mineral nutrients during several years of cultivation without external inputs and ways to re-build the fertility conditions of the soils represents a major research challenge if the long-term sustainability of cocoa production is to be ensured. As an initial solution to the fertility problem, blanket application of fertilizers has been recommended for the cocoa farms in the country. However, there is the need to study the consequences of such recommendations and device possible strategies to address them.

Decline in national production and productivity has been noted since the 1970s (Appiah *et al*., 2000). Depleted soil fertility as a result of long term low input cocoa cultivation has been identified as the major cause of the decline of cocoa yield on smallholder farms in Ghana. Lack of fertilization leads to yield and soil fertility decline after about 10 years of cultivation. Regarding separate elemental effects, significant yield increase were generally reported following the use of P and K, whereas N had no effect or depressed cocoa yield (Ahenkorah *et al*., 1987).

Although there have been output increases in recent times around 700,000 metric tonnes, this figure falls below the national target of one million metric tonnes anticipated by the year 2012. Soils in the cocoa producing areas in Ghana after several years of cocoa cultivation are exhausted of their nutrient reserves. For sustainable cocoa production including the recovery of soil fertility in degraded areas, it has become necessary for external plant nutrient replenishment; therefore, the use of both recommended organic and inorganic cocoa fertilizers.

The paper brings together integrated plant nutrient management strategies for possible adoption for sustainable and competitive cocoa production as part of the strategy to achieve higher production output.

MATERIALS AND METHODS

Assessment of the status of soils within the cocoa belt

In this study, information regarding the major soil groups and the rainfall patterns and distribution better portrayed by the Length of Growing Period (LPG) are important. Appendix A shows the major soil groups in Ghana. Acrisols (75%), Lixisols (10%), Ferralsols (9%) and Nitisols (3%) constitute 97% of the total land area within the cocoa belt. Soils in these areas are largely fertile with soil pH varying from 4.5 to 7.2 and can support cocoa production. Appendix B shows the LGP of the Cocoa Belt in Ghana. These areas experience bimodal rainfall pattern with total rainfall between 800 - 1200 mm. The LPG of the cocoa growing areas lies within 230 to 350 which are considered ideal for cocoa cultivation. Cocoa cultivation could have been at the optimal level in these areas, but due to several years (130 years) of unceasing cocoa production, the solid phase of these ideal soil types (Appendix A) is not good, because of the continuous depletion of the nutrients without external nutrient replenishment.

Eight hundred soil samples were randomly taken from two levels: 0-15 and 15-30 cm in the cocoa belt principally based on soil groups and rainfall patterns and distribution. Standard soil preparations were done prior to analysis. Organic C was analyzed by the Walkley and Black method (Blakemore *et al*., 1972). Total N will be determined by Kjeldahl digestion and distillation method (Bremmer and Mulvaney, 1982). Available P was extracted from the soils using 0.5M $NaHCO_3$ (Olsen *et al.*, 1954) and P in the extract measured by the molybdenum blue method. Soil pH was measured in 1:2.5 soil/water ratio using glass electrode. Exchangeable cations were extracted with l M ammonium acetate 1:50 soil: extractant ratio for 2 hours and filtered through Whatman No. 42 filter paper. The cations in the extracts were determined by Atomic absorption spectrophotometer.

RESULTS AND DISCUSSIONS

Nutrient status of soils and plant parts

Nitrogen (N), phosphorous (P) and potassium (K) in total constitute 6.5, 0.38 and 5.02 respectively of the various parts of cocoa (Table 1). The level of N is highest in the beans which is exported out of the farm and subsequently marketed outside the country. The nutrients in the leaves and the pod husk are retained in the farm and later returned to the soil after decomposition.

Table 1: Nutrient levels in parts of cocoa

	%N	%P	%K
Beans	2.81	0.18	0.62
Cocoa pod husk	2.10	0.04	2.20
Leaves	1.60	0.16	2.20

The levels of other nutrients especially P in the various parts compared with N is very low. This indicates that, N is the nutrient taken up at the highest concentration by cocoa. Thong and Ng, 1978 indicated that potash (K_2O) is required at the highest concentration at the nursery and immature stages of cocoa with uptake of 3 kg ha^{-1} and 188 kg ha^{-1} respectively. However, N and K requirements at the nursery and immature stages are comparable, i.e. 2.5 kg N ha^{-1} and 3.0 kg K_2O ha^{-1} for nursery plants and 140 kg N ha^{-1} and 188 kg K_20 ha^{-1} for immature plants. During the early production years, and in mature trees, the difference in the N and K requirements are higher compared with the first two developmental stages of the crop.

The status of the major nutrient elements within the Ghana cocoa belt including the levels of the nutrients consumed and the quantities remaining is shown in Table 2. Nitrogen and K are the least consumed major nutrients, therefore, their presence in the soil are very high. Conversely, consumption of P is about ten times higher than that of K and about eight times that of N. Only 37% of the P is left in the soil, therefore, its presence in the soil is very low compared with the other major nutrients which are being produced in the soil by other processes.

Table 2: Status of the major nutrient elements within the Ghana cocoa belt

Nutrient	Consumed (%)	Remaining (%)
Nitrogen	8	92
Phosphorus	63	37
Potassium	6	94

The high levels of N observed in the soils may be due to the presence of N fixing leguminous crops whereas the abundance of K may partly be the montmollonitic mineral clays (2:1 clay type) in the soils. Whereas more N and K can be released into the nutrient pools by other means, P fixation by the soils prevents the release of P into the nutrient pool. Additionally, cocoa pod husk contains very high levels of K (2.20%) (Table 1), which can be recycled. The high solubility of the K in the pod husk makes it readily available to plants, although, its movement is controlled by other soil colloids. Nitrogen and P ratios should be lowered to less than 2 but the ratios have often been high in the soils. Ratios of exchangeable bases to N should be 8.9 or higher. Soil pH is one single factor that has influence on the availability of the nutrients in the soil pool and the plant. The soil pH of 4.5 to 7.2 observed generally indicates that these soils can support cocoa but the optimal range is pH 5.5 to 6.5. With soil pH, one expects the base saturation to be at least 60% with semi-permeable depth of 1.2 m for optimum exploitation of the nutrient elements by the root system. However, the soils examined had base saturation lower than 30%.

Strategic action for competitive and sustainable cocoa production

Replacement of exported nutrients from the soil through the beans is critical. In view of the nutrients exported from the soil (Table 3), the average nutrients taken up since cocoa cultivation started in the country is extremely high. For an average production of 311,000 tonnes of dry cocoa beans per annum for a period of 75 years, the total production will be about 23.3 metric tonnes. Considering the replacement of the nutrients in the soil (Table 3), over 3.2 million metric tonnes of ammonium sulphate, 218,000 metric tonnes of triple superphosphate and 289,200 metric tonnes of muriate of potash or their equivalents will be required to replace the nutrients loss through the beans over the years. The technique to be used in replacing the nutrients in the soil for the efficient utilization by the crop is the next consideration. The ensuing action is to alter the soil physicochemical properties to improve the nutrients uptake. With the replacement of the soil nutrients through the plant parts, only nutrients lost through the beans is necessary to be considered, as the nutrients in the other parts are returned in one way or the other to the soil. Nutrients from the leaf litter are recycled and released to the soil after decomposition. Nutrients from the pod husk, although returned to the soil; they are concentrated at the breaking points. This implies the nutrients are moved from its original location and re-concentrated at the breaking points which means the nutrients are within the farms.

Nutrient replacement strategy

Replacing the nutrients lost from the soil can come from different sources. The external sources could be grouped into inorganic, organic and natural fertilizer sources. With the inorganic granular fertilizers, the recommended ones used in cocoa fertilization have high P and K in the formulations, for example Cocofeed - N:P:K 0:30:20, Cocoa Master - N:P:K 1:21:19 + 9CaO + 6S + 6MgO + 1B and Asaase Wura - N: P: K 0:22:18 + 9CaO + 7S + 6MgO. All these granular fertilizers are applied at 375kg ha^{-1} by broadcasting. Inorganic foliar fertilizers adopted for cocoa are the Cocoa Sett, Lifet A+, and Sidalco liquid fertilizers which comes in three formulations of Sidalco Balanced - N:P:K 10:10:10; Sidalco Nitrogen Rich - N:P:K 20:2:4 and Sidalco Potassium Rich - N:P:K 6:0:20. Frequency of application for all these liquid fertilizers is once every month at a rate of 10 mLs of the liquid fertilizer in 11 litres of water (100 mLs ha^{-1}). With the foliar application, contacts with antagonistic nutrients that may create “artificial shortage” of nutrients are avoided and also a faster way of correcting nutrient deficiency.

Organic fertilizers so far recommended for use on cocoa plantations contain all the nutrients, but the quantities or concentrations of the nutrient elements are variable from one type to the other. Organic fertilizers so far tested are poultry manure (PM) and cocoa pod husk ash (CPHA). Application rate of CPHA is 370 kg ha^{-1} yr^{-1} and that of PM is 1800 kg ha^{-1} yr^{-1}. Other forms available to farmers are Elite organic fertilizer and Natural organic fertilizer, both has application rate of 1,000 kg ha^{-1} yr^{-1}. In all cases, the method of application is broadcasting and time of application is at the onset of the rains.

Natural fertilizers such as phosphate rock (PR) is cheaper compared with the soluble phosphorus fertilizers like triple superphosphate and single superphosphate. Togo phosphate rock is the type closer to Ghana. The very low solubility of the PR is the drawback of using this cheaper source of P fertilizer. To improve on the solubility, particle sizes are reduced to increase the surface area in order to increase their solubility. The application rates are based on reactivity and the best application rate for cocoa when using Togo PR is up to 700 kg ha^{-1} yr^{-1}. The PR is applied during the onset of the rains by broadcasting. Other natural fertilizers or biological fertilizers have been tested includes Nutrismart, and Natural Asontem. Nutrismart is an enzymatic granular fertilizer that enhances the release of various nutrients from the soil.

Nutrismart application rate is 8 kg ha^{-1} yr^{-1} which is lower compared with the other granular fertilizers.

Inorganic fertilizers alone just like organic fertilizers alone are unable to sustain cocoa productivity. Therefore, the strategy would be for cocoa farmers to integrate the application of these tested fertilizers to ensure balanced nutrient supply and a higher positive effect on cocoa yields and soil health.

CONCLUSIONS AND RECOMMENDATIONS

Nutrients requirements of cocoa and their availability in the soils of Ghana have been shown to be low from the discussion. Cocoa production can only be at sustainable and competitive levels if external source of fertilizers are incorporated. It could be noted from the fertilizers recommended for use in the country that N and basal cations are lacking in some of the formulations. There is therefore the need to integrate the fertilizers that contains N and basal cations with those lacking these elements in order to increase the level of N and basal cations in the soil thereby increasing yields and also enriching the base saturation of the soil. There is the need for cocoa farmers to adopt the integrated application of all these tested fertilizers to ensure balanced nutrient supply, a higher cocoa yields and a good soil health. These recommendations if addressed will ensure sustainable and competitive cocoa production from the Ghana cocoa belt.

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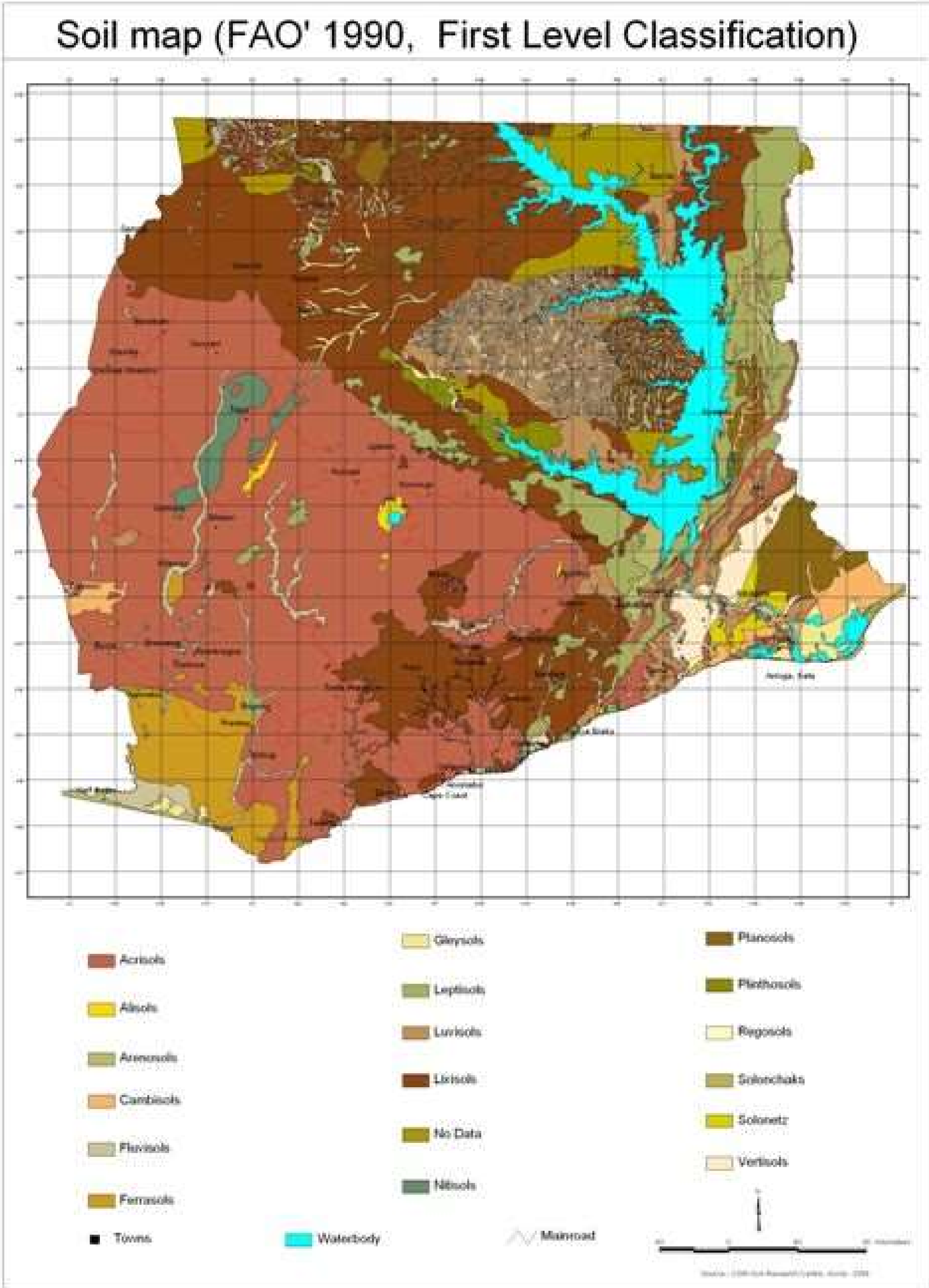
Appendix A: Major soil groups within the cocoa regions of Ghana



Appendix B: Total length growth periods in the different agroecological zones of Ghana