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FACTORS OF AGRICULTURAL PRODUCTION AND THE POSSIBILITY OF AGRICULTURAL GMO PRODUCTION IN GHANA

Key words: genetically modified organisms (GMOs), factors of production, land, labour, capital, productivity, agricultural production, Ghana

ABSTRACT. This research work aims to pinpoint the actual production factors that are deteriorating and explore the essence of genetically modified organism (GMO) in helping to combat the degrading nature of production factors in Ghana. Agriculture has always employed dynamic processes from seed sowing to harvest over the years, but there are key factors that are non-negotiable in the sector, production factors. There has been diverse research and view on what production factors are inclusive in agriculture's production factors. This notwithstanding, aside these divergent views, land, labour and capital still remain the most essential part of the production factors in agriculture. Ghana just like any other country has employed these factors but is lagging in hitting the productivity mark. There has been numerous research works, to dissect the roadblocks to agriculture yields in Ghana. Genetically modified organism as a section of biological innovation will be of an immerse and complete supplement to the production factors in Ghana if we look forward to achieving a bountiful agriculture harvest. The paper comprises selected facts and opinions on the GMO production development in Ghana in the nearest future and some factors influencing the development of GM food production, including land, labour and capital in Ghanaian agriculture.

INTRODUCTION

The world's agriculture has gone through an evolutionary phase. In the development of human society, the shift to a relatively settled way of life from a nomadic hunter-gatherer lifestyle was enormously profound and made possible only by the development and adoption of early agricultural practices. In turn, this change in human lifestyle had major impacts on the environment of agriculture and hence the traits and characteristics of plants and animals that were favoured both consciously and unconsciously by humans.

Very often traits suited to species growing without human protection or husbandry were not suitable for agriculture and were rapidly lost, while others were specifically favoured by the more protected environment agriculture provided, they increased in frequency [Thrall et al. 2010, p. 405-408]. Species that increased in frequency, can be attributed to favourable factors, like climate, soil fertility, changing seasons amongst others. The world's agricultural sphere has metamorphosed over the years to what we currently have. Present day farming and animal rearing also has its ups and downs, which is being tackled head on.

The first step to assess prospects for the present and the future of agriculture production does not only depend on technology, but also on elements that impact the development of agriculture, including livestock or crop production. These factors may vary from country to country but may also have similar factors of production cutting across the entire globe. Some countries have been unable to attain self-sufficiency in agriculture production due to negligence of certain determinants of agriculture production, e.g., factors of production including labour, capital, and land. This notwithstanding, technology and innovations in recent years, via genetic modification technologies are the key support system for a bounty yield and output. Over the past decade, research into, and the deployment of GM technologies has increased rapidly, particularly in the developing world to help boost the agriculture sector [Carrière et al. 2010, p. 5-9].

In line with this study, much focus is on Ghana, being one of the developing countries in the world, it is also experiencing this agricultural revolution. It is found on the west of the African continent with a population of 31,073 million according to UNCTAD 2020 data. Ghana's agriculture is predominantly smallholder, traditional and rain-fed [SRID 2021].

About 136,000 km^2 of land, covering approximately 57% of the country's total land area of 238,539 km^2 is classified as agricultural land area out of which 58,000 km^2 (24.4%) is under cultivation and 11,000 hectares under irrigation. About 60% of all farms in the country are less than 1.2 hectares in size, 25% are between 1.2 to 2.0 hectares, with a mere 15% above 2.0 hectares. The mean farm size is less than 1.6 hectares. Small-size and medium-size farms of up to 10.0 hectares account for 95% of the cultivated land [SRID 2021]. In the labour sector, about 52% engage in agriculture labour [SRID 2021]. Crop and livestock farming in Ghana vary from the ecological zones and seasons in the sixteen regions of Ghana.

Agricultural factors, including labour, land and capital are crucial for agricultural production development in the future and they also influence the biological innovation in agricultural production of Ghana, e.g. introduction of genetically modified organisms. The main aim of the study was to analyse agricultural production factors and their relations as well to discuss their influence on the possible production of GM food in Ghana.

MATERIAL AND METHODS

The research methodology showcased the research approach as well as research materials used together information on the research topic, through both primary and secondary sources. Data for the study have been gathered mainly from secondary sources via electronic data. Research materials of the paper include data from FAOSTAT, the World Bank (WB) and the United Nations Conference on Trade and Development (UNCTAD), as well as data of the Ministry of Food and Agriculture of the Republic of Ghana (MOFA). An in-depth analysis of the literature on GMO development and introduction to production in Ghana was carried out.

For the purpose of this study, a short qualitative survey was conducted to collect opinions from actors in the agricultural field including eight farmers, four agricultural extension officers, two researchers, and six agriculture lecturers as well as agriculture engineers. The opinions were collected in 2021 from a total of 20 people. The survey provided insight into reasons that will push GMO production from confined field tests to commercialized farming. The aim of the questionnaire was to collect both key and underlying factors that will influence GMO production as well as the future of GMO in Ghana. The survey was carried out as online interview via google forms. The questionnaire form included 9 open ended questions in total, including mainly questions about the major factors influencing GMO production in Ghana, and the current perception of GMO production in Ghana among farmers, the possible benefits and threats of GMO plant production in Ghana.

PRODUCTION FACTORS OF AGRICULTURE IN GHANA

Ghana is divided into six major agro-ecological zones namely: Rain Forest, Deciduous Forest, Forest-Savannah Transition, Coastal Savannah and Northern (Interior) Savannah which comprises of Guinea and Sudan Savannahs. The bimodal rainfall pattern in the Rain Forest, Deciduous Forest, Transitional and Coastal Savannah zones gives rise to major and minor growing seasons. In the Northern Savannah zones (Guniea and Sudan Savannah), the unimodal rainfall distribution results in a single growing season. The rainfall determines largely the type of agricultural enterprise carried out in each zone [Wawo et al, 2014].

According to the Ghana Living Standards Survey, Round 6 main report (2014), households in the forest Zone produced 55% of the crops harvested and 58% value of sales in the 12 months period from October 2012 to October 2013. Livestock production is concentrated in the Savannah areas and offshore fishing mainly in the Coastal Savannah zone [GLSS 2014, Wawo et al. 2014].

Ghana's climate is influenced by the hot, dry and dusty-laden air mass that moves from the north east across the Sahara and by the tropical maritime air mass that moves from the south-west across the southern Atlantic Ocean. The climate ranges from the bimodal rainfall equatorial type in the south to the tropical unimodal monsoon type in the north [Dickson, Benneh 1988, Benneh 1990]. The rainfall generally decreases from the south to the north. The wettest area is the extreme southwest where the rainfall is over 2,000 mm per annum. In the extreme north, the annual rainfall is less than 1,100 mm. The driest area is in the south-eastern coastal tip where the rainfall is about 750 mm. Much of the rain falls in intense storms of short duration, especially at the 7 beginning of the season resulting in heavy runoff and erosion [Dickson, Benneh 1988, Benneh 1990]. There are two main seasons: the wet and the dry seasons. Average temperatures range from 21°C to 28°C with a relative humidity between 77% and 85%. In the southern part, there are two rainy seasons: April through June and September through November. Squalls occur in the northern part during March and April, followed by occasional rain until August and September, when the rainfall reaches its peak [Wawo et al. 2014].

According to Daniel Wawo et al. [2014] most of the soils of Ghana are developed on thoroughly weathered parent materials. Alluvial soils (Fluvisols) and eroded shallow soils (Leptosols) are very common to all the ecological zones in Ghana. In general, most of the soils are plagued with inherent or human induced infertility [MFA 1998]. The soils in the Forest zone are usually porous, well drained, loamy and are distinguished from those of the Savannah zones by the greater accumulation of organic matter in the surface. They can be found in areas underlain by various igneous, metamorphic and sedimentary rocks, which have influenced the nature and properties of the soil [MFA 1998]. Soils of the Savannah zones are low in organic matter (less than 2% in the topsoil) and they have high levels of iron concretions and are susceptible to severe erosion. Because of that well-drained upland areas tend to be droughty and they tend to develop cement-like plinthite. These conditions cause necessity of incorporating manure regularly into the soils in the Savannah zones [MFA 1998]. A high degree of gully erosion is common in the Savannah zones along the north and south, and to some extent along the west. According to John Edem Kongor et al. [2019, p. 1455] "inadequate or lack of prudent soil fertility management by cocoa farmers leads to nutrient depletion in cocoa production fields". The topography of the country is mainly undulating with most slopes less than 5% and many not exceeding 1%. The topography of the high rainforest is, however, mainly strongly rolling in Ghana. The uplifted edges of the Voltaian Basin give rise to narrow plateau between 300 to 600 m high. Despite the general undulating nature of the terrain, about 70% suffer from moderate to severe soil erosion [Boateng 1998].

Farmers acquire land through different channels. Originally, land was acquired through settlement, but there is no unclaimed land remaining in Ghana [Bakang, Garforth 1998]. The most common methods of acquiring land are allocation or inheritance of land.

Other "nonmarket" systems that exist are borrowing of land and gifts of land. Renting, sharecropping, and purchasing land are "market" channels of land acquisition that are known but not necessarily practiced in all communities. The prevalence of each of these modes of acquisition differs greatly throughout the country [Lambrecht 2016].

Klaus Deininger [2003] indicates owning a property in the developing world can be a crucial advantage economic activity of an individual. "More than 80% of land in Ghana is not registered and mostly belongs to family members with no clear title deeds of ownership. Therefore, this affects the individuals in need of land for agriculture purposes" [Deininger 2003]. This form of land ownership and inheritance system in Ghana deprives the people of owning the land with the women most affected due to the bargaining power within the family [Lambrech, Asare 2016]. Carmen Diana Deere et al. [2013] emphases on the ability to take advantage of economic opportunities and cope with risks and, most importantly, for the welfare of the household. Land reforms in Africa were considered an extraordinary case with its abundance of the land. Still, in recent times, land in Africa is scared due to the high population growth affecting the socio-economic development of the individual and economy. The lack of land markets, however, prevents the emergence of private land rights and security in particular land property and hinders the development of agriculture as a result of avoiding farmers from expanding on their holdings [Holden et al. 2006]. This, however, hinders the improvement for the small-scale farmers since they have inadequate credit facilities and are not able to use their land titling as collateral to expand their holdings. Based on this, it can be said that the increasing population pressure in the country affects the commercialization of the agricultural systems. Land rights have led to a low or decrease in land productivity as a result of lack of infrastructure, low level of technology, and market efficiency [Amanor 1999].

Table 1 shows the distribution of Ghana's agricultural land and its structure. The land under permanent meadows and pastures constitutes 50% of the total Agricultural land, followed by the arable land (32%) and the land under permanent crop production making up 18%. Majority of Ghana's land area is in the Savannah zones where the land is under permanent meadows and pastures in the northern sector of the country.

Table 1. Agricultural land and its structure in Ghana in 2018

Type of Area	Area [thousand ha]	Structure of agricultural land [%]
Agricultural land, including:	1,4782.74	100.0
– arable land	4,700.00	31.8
– land under permamanent crop	2,700.00	18.3
– land under permanent meadows and pastures	7,382.74	49.9

Source: [FAOSTAT 2018]

Agriculture in Ghana serves as a key livelihood strategy for many poor families in rural areas, where labour-intensive, smallholder farming is the predominant source of income. Agricultural growth has been found to be more effective than non-agricultural growth in reducing extreme poverty [Naqvi et al. 2011]. One of the most important agriculture inputs in developing countries is the labour provided by family members on their own farms as farm labour and commonly measured in hours or days over an extended reference period, such as the last season or the last year [Gaddis et al. 2019]. Data on farm labour are important for a range of literature strands in development economics – such as analyses of agricultural productivity [Restuccia, Santaeulalia-Llopis 2017, Gollin, Udry 2019], agricultural household models [LaFave, Thomas 2016], rural labour markets [Dillon et al. 2019], and gender differences in agriculture [WB 2014, Damon, McCarthy 2019]. A range of recent studies, for example, highlight lack of access to family members' labour, particularly male labour, as one of the main factors constraining women farmers and a key determinant of the gender gap in agricultural productivity [WB 2014, Kilic et al. 2015]. In Ghana, "labour on the plantation is divided by tasks carried out based on physical attribution, seasonality, and sometimes through discretionary decisions at the supervision level" [Gyapong 2019, p. 8]. The tasks are also divided by men and women, with men having more opportunities to take up specific tasks. Workers are deployed through the gang system often consisting of 25 workers and harvesting, pruning, spraying, fire control and loading (they load and transport the palm fruits to the processing site) are reserved for men. The other tasks, like slashing is done by both genders, while loose-picking is usually a woman's task. In the peak seasons, harvesters usually employ their own workers to transport the harvested palm bunches to specific locations on the farm and they are called 'carriers'. There are also service workers in the farms, who are mostly skilled men engaged in technical operations, like mechanical engineers and fitters, carpenters, plumbers, vulcanizers, heavy-duty truck operators and drivers. There is one more group of workers in the farms called the support workers. They are mainly responsible for security and supervising fire control in the dry seasons [Gyapong 2019]. Yeboah Adwoa Gyapong [2019] also observed that there are no women in management, administration and supervision of the farms.

The remuneration scheme of the workers is premised on a time-based piece rates system [Gyapong 2019]. Workers usually struggle with consistent delays and low differentiation. The baseline daily wage is about USD 2.33 and applies to work and support service. This piece rate daily wage is about forty-five percent national minimum wage of USD 1.61. The casual workers in the skilled service and permanent skilled receive usually a higher daily wage between USD 3.24 and USD 4.15 plus allowances [Gyapong 2019].

The number of hours worked in a week by most skilled agricultural, forestry and fishery workers is 20-29, shows that the number of skilled agricultural, forestry and fishery workers increase as the number of hours worked increase. However, after 20-29 hours

of work a week, the number of skilled agricultural, forestry and fishery workers decline with increasing number of hours of work [GSA 2015].

The proportion of persons aged 15 years or older in agricultural households who are engaged in agricultural activities is 41.6%. Agriculture is a male dominated activity; the proportion of males (55.2%) in agricultural households engaged in agriculture is about two times as high as that of females (28.3%). This pattern holds true among the male and female populations of agricultural households. However, among the males, the peak is at 55-59 years age group with a proportion of 89.4% while for females, the peak is at 65-69 years age group and the proportion is 58.2%.

Table 2. Persons 15 years or older engaged in agriculture in Ghana in 2018

Age	Total (male and female)	
	Number of persons	Structure [%]
15-35	902,174	29.7
36-59	1,605,274	52.9
60+	529,933	17.4
Total	3,037,381	100.0

Source: [GSA 2018]

Table 3. Changes of employment in the agricultural sector in Ghana from 2000 to 2019

Year	Share of employment in agriculture [%]	Dynamic of changes	
		2000 = 100.0	Previous year = 100.0
2000	55.0	100.0	100.0
2005	54.9	99.8	99.8
2010	50.1	91.1	91.3
2015	35.1	63.8	70.1
2019	29.7	54.0	84.6

Source: [WBG 2021]

Table 3 shows the decline in employment for the agricultural sector from 2000 to 2019. This can be attributed to the growing nature of the service sector over the years, and also the agricultural sector was unattractive because of the low level of income. The recent discovery of oil in Ghana which affected the structure of the country economy, also worsened the plight of the agricultural sector.

Farming systems in Ghana have evolved to the extent that mechanization of some operations has become necessary. Currently, the main demand for mechanization is for land preparation and harvesting in some cases. Most land preparation is undertaken using four-wheel tractors, and since few farmers can afford to own these, they are available for hire through parallel supply systems. In Ghana, there are currently two parallel supply channels for agricultural mechanization services for farmers; a government-sponsored Agricultural Mechanization Services Centre program; and a private sector system of importers, machinery service providers (many of which are medium-scale farmers), and repair and maintenance shops.

Table 4. Machinery archive showing the usage of agricultural tractors and harvesters from 2000 to 2003

Year	Machinery	Quantity
2000	harvesters-threshers	19
	tractors agric total	3,570
2001	harvesters-threshers	19
	tractors agric total	3,600
2002	harvesters-threshers	19
	tractors agric total	3,600
2003	harvesters-threshers	19
	tractors agric total	3,600

Source: [FAOSTAT 2021]

Until recently, most cropped land in Ghana was cultivated manually, and use of animals or tractors for plowing was limited, despite early government sponsored mechanization programs in the 1960s. Mechanization is most prevalent in the Upper West and Northern regions and in the Greater Accra region, regions where 75% or more of farmers report spending on mechanization. The least mechanized regions are the Central and Ashanti regions, where less than 10% of farmers report spending on mechanization. One reason for this regional distribution is that the dominant. form of mechanization is tractor plowing, and this is more relevant in regions that grow field crops than in the forest and cocoa growing areas. Larger farms with more than five hectares are much more mechanized than smaller farms in both the North and the South parts of the country. While the largest farms often own their own tractors, most other farms are too small to justify such a lumpy investment and must hire in tractor services. Some medium-sized farms are able to justify purchasing a tractor by hiring out tractor services once they have met their own mechanization needs [Diao et al. 2019].

NPKs are the most utilized fertilizer in the country (Table 5). There was an 84% increase in fertilizer apparent consumption in 2017 as compared to 2016. The huge increase was due to Planting for Food & Jobs and normal fertilizer subsidy that run in the country [AfricaFertilizer.org 2017].

Table 5. Use of fertilizers in Ghana from 2013 to 2017

No.	Fertilizer	2013	2014	2015	2016	2017
		tonnes				
1	NPK	113,812	39,344	137,902	132,632	210,387
2	urea	36,104	-	18,253	39,035	88,259
3	ammonium sulphate	54,863	6,282	64,015	23,268	43,865
4	organic fertilizers	6,465	5,523	7,818	8,747	37,568
5	other fertilizers	16,287	10,233	11,077	8,532	9,582
6 = 1+2+3	total artificial and chemical fertilizers	204,779	45,626	220,17	194,935	342,511

Source: [Africafertilizer.org 2017]

RELATIONSHIP BETWEEN PRODUCTION FACTORS

The organization of production processes in agriculture is based on the appropriate binding together of the individual factors of production (land, labour and capital). The connection method of production factors in certain production processes is defined as technique of production. Each farmer in the manufacture of products has to choose the appropriate manufacturing techniques. Mutual relations of production factors depend mainly on the relative prices of factors of production and performance. Factors of production can replace each other, so they are substitutable provided that there is a certain, often very large number of production techniques [Kusz 2015]. If there is only one production techniques, substitution of production factors is impossible [Rembisz 2008]. In a market economy the correct allocation of factors of production (in terms of their relationship and their level) is the basis for effective management [Kusz 2015].

Analysis of the world's agricultural diversity indicates the existence of some general regularities, based on which the proportions of the factors of production are arranged, determining the level and structure of agricultural production costs. In each country there are in a particular historical moment some resources of production factors, which determine their supply and prices. This in turn affects the way the management of enterprises by the choice of the optimal production techniques. Pricing system makes the combination of factors of production in each country and in all circumstances different. With the abundance of land and scarcity of capital ratio of cost of land to capital is that it pays off to combine large areas of land with a relatively small amount of capital. Production remains at low levels of capital intensity. But where there is a large abundance of technical resources (capital), their price is relatively low. Because of that, the share of capital in the production process will be greater [Yamaoka 1969, Klepacki, Żak 2013].

In the case of agriculture, there are two important types of relationships: (i) between labour and capital inputs and land resources; (ii) between the resources of land and capital and labour resources. The first type of relationship is used to measure the so-called the intensity of agricultural production. The second type of relationship is in turn the meter of equipping labour with land and other production means, particularly technical [Kusz 2015]. The relationship between the production factors in Ghana, comparing to Africa are discussed below (Table 6 and 7).

In making analysis and conclusive deductions on the relationship of production factors, it is subject to the elements involved in the process. Africa as a whole in Tables 6 and 7, is to measure the level of progress achieved in agriculture with relation to production factors, and how total input is reflected on member countries. From Table 6 (year 2000), relationship between land/labour for Ghana stands at 3.4 ha per person is averagely workable, and it shows how proportionate the correlation between land and labour balances. In view of

Table 6. Relationship between production factors in Ghana in 2000

Relationships	Unit (description)	Ghana	Africa
Relationship: land/labour or labour/land			
Total agricultural land/employment in agriculture	ha/person	3.4	6.8
Total employment in agriculture/ total agricultural land	no of person/ 100 ha	29.4	14.7
Relationship: capital/labour			
Total number of agricultural tractors/ total employment in agriculture	no of tractors/ 1,000 persons	0.872	3.338
Total number of harvesters-threshers/total employment in agriculture	no of harvesters-threshers/1,000 persons	0.005	0.231
Gross fixed capital formation (in agriculture, forestry and fishing)/total employment in agriculture	USD, 2015 prices/ person employed in agriculture	105.6*	n/a
Relationship: land/capital or capital/land			
Total agricultural land/total number of agricultural tractors	ha/agricultural tractor	3,895.1	2,035.6
Total area of cereal harvested/total number of harvesters-threshers	ha/harvester-thresher	68,770.1	2,363.1
Gross fixed capital formation (in agriculture, forestry and fishing)/total agricultural land	USD, 2015 prices/ ha	31.1*	n/a
Total amount of NPK fertilizers use/total cropland	kg NPK/ha	2.0	16.6
Total amount of pesticides use/total cropland	kg/ha	0.013	0.273

* Data of 2001
Source: [FAOSTAT 2021, FAO 2020]

this, the opposite side labour/land falls in line with the prior. This effectively should push for a positive productivity.

Capital/labour: this relationship has been quiet problematic in the year 2000. This is actually an improper relation. Machinery in terms of tractors used for harvesters are poorly distributed. In 2000 Ghana has (0.872 tractor per 1,000 persons), explaining why there is so much post-harvest losses because the use of more manual activities to harvest which is very time consuming. This also reflects sin Africa's position on capital and

Table 7. Relationship between production factors in Ghana in 2019

Relationships	Unit (description)	Ghana	Africa
Relationship: land/labour or labour/land			
Total agricultural land/total employment in agriculture	ha/person	3.5	5.0
Total employment in agriculture/ total agricultural land	no of person/ 100 ha	28.7	20.0
Relationship: capital/labour			
Total number of agricultural tractors/ total employment in agriculture	no of tractors/ 1,000 persons	0.747*	2.965*
Total number of harvesters-threshers/total employment in agriculture	no of harvesters-threshers/1,000 persons	0.004*	0.201*
Gross fixed capital formation (agriculture, forestry and fishing)/total employment in agriculture	USD, 2015 prices/ person employed in agriculture	365.9**	n/a
Relationship: land/capital or capital/land			
Total agricultural land/total number of agricultural tractors	ha/agricultural tractor	3,938.1*	2,058.7*
Total area of cereal harvested/total number of harvesters-threshers	ha/harvester-thresher	68,770.1*	2,363.1*
Gross fixed capital formation (in agriculture, forestry and fishing/total agricultural land	USD, 2015 prices/ ha	106.2**	n/a
Total amount of NPK fertilizers use/total cropland	kg NPK/ha	26.1	24.1
Total amount of pesticides use/total cropland	kg/ha	0.074	0.299

* Data of 2003, ** data of 2017
Source: [FAOSTAT 2021, FAO 2020]

labour 3.338 tractor per 1,000 persons. Although Africa has abundant access to labour, capital in terms of labour is greatly lagging, which has affected contribution to the world's agriculture. This finding shows the essence of capital as a major contributing factor to achieving maximum productivity.

Capital/land: for the year 2000, although GMO discovery was in existence, its impact was quite limited in reaching Africa. Fertilizer was more rampantly used to improve yield. Ghana did work hard enough to be able to use 2.0 kg NPK/ha.

Nineteen years down the line in agriculture (2019), averagely for Africa the total agriculture land/person has reduced to 5 ha per person explaining how much these lands are being used for other purposes. For Ghana having a minor increase by 0.1 amounting to 3.5 ha per person. Looking at the opposite relationship (labour/land), although the world is aiming towards zero hunger; the employment in agriculture has decreased drastically with the agricultural land remaining the same creating an imbalance. Interestingly, Africa increased from 14.7 (number of persons per 100 ha) to 20.0 (number of persons per 100 ha). Deducing from this figure, the world-wide decline in employment for agriculture can be said to be country specific in this case because Ghana had a reduction from approximately 29.4 to 28.7 (number of persons per 100 ha). The implication of this effect will be to increase capital (machinery to supplement the declining agriculture employment for Ghana.

Capital/labour: in 2003, Ghana and Africa as a whole had a reduction in the access to capital (tractors) which adversely affect productivity. Ghana registered reduction in the access to agricultural tractors from 0.872 (number of tractors per 1,000 persons) to 0.747 (number of tractors per 1,000 persons). This is because although the employment in agriculture is reducing, the numbers of tractors still remained the same with some broken down, without repairs and abandoned. Still with capital/labour: Ghana's gross fixed capital formation (in agriculture, forestry and fishing, USD, 2015 prices)/total employment in agriculture and per 1 person employed in agriculture in 2017 has improved drastically since the year 2000. This can be attributed to improvement in the area of scientific research and the use of technology in agriculture.

Land/capital or capital/land: in 2019, Ghana had 3,938.1 (ha/1 agricultural tractor), and Africa with 2,058.7 (ha per 1 agricultural tractor). The average tractor situation in Africa is fairly better than Ghana. This is because of lack of intervention policies for farmers and spare parts for broken down tractors. Aside this, most farmers in Ghana cannot afford to purchase tractors, so they hire them on day to day basis when needed. In the area of capital formation, much work needs to be done. Total gross fixed capital formation (in agriculture, forestry and fishing, USD, 2015 prices)/total agricultural land in 2017, had Ghana standing at 106.2 (USD, 2015 prices per 1 ha) which is averagely manageable but can be improved over time, this not standing the figures correlate with the agricultural land size.

In summary, it can be ascertained that, Ghana and Africa as a whole have enough agricultural employment, although the agriculture population is declining over time. The key production factor that needs to be assessed and improved stands on capital (in terms of machinery and gross capital formation). This can be achieved by fast tracking, policies or initiatives on harvesters, tractors as well as industrial research in the area of agricultural capital.

AGRICULTURAL GMO PRODUCTION IN GHANA: INTRODUCTION AND PERCEPTIONS

Generally, genetically engineered (GE) crops are usually see as a factor of increasing agricultural productivity (increasing crop yields). However, according to Israel D.K. Agorsor et al. [2016, p. 1] "efforts to promote genetic engineering agriculture in Africa have been met with some amount of resistance". There were ongoing confined field trials of some selected genetically engineered crops in the second decade of the XXI century in Ghana, but "analysis of ongoing genetically modified organism debates and published opinions shows a considerable amount of opposition to GE agriculture and GMOs in Ghana [Agorsor et al. 2016]. The general view that agricultural systems in developing countries of Africa have not delivered the desired results. Most African countries (including Ghana) have not moved towards the adoption of GE technologies in their agriculture modernization efforts [Agorsor et al. 2016].

In Ghana, one of the steps of introducing GE crops was the establish the National Biosafety Committee. The main goal of the Committee is to oversee the formulation and adoption of a national biosafety law. Ghana's Biosafety Act of 2011 (Act 831) provided for the establishment of a National Biosafety Authority, taking over the functions of the National Biosafety Committee to regulate all activities pertaining to biotechnology in Ghana. The National Biosafety Authority (NBA) in Ghana was established by the Biosafety Act No. 2 of 2009 to exercise general supervision and control over the transfer, handling and use of genetically modified organisms (GMOs), which production involves the manipulation of the genetic material of organisms through genetic engineering procedures. Many citizens of Ghana are opposed to GM foods and some studies showed that the confidence of the Ghanaian public in the ability of government's regulatory systems to handle issues related to biotechnology is very low. People expect the establishment of a special body to regulate biotechnology research and activities. Attempts to pass a plant breeders bill into law "to provide for the grant and protection of plant breeder rights and for related matters" has provoked a national debate on GMOs. In the process, some participants of the debate have called for the repeal of the Biosafety Act of 2011 [Agorsor et al. 2016].

For the purpose of this study, a qualitative survey was conducted to collect opinions from actors in the agricultural field including farmers agricultural extension officers, researchers, agriculture lecturers, and agriculture engineers. In order to understand the future of GMO production in Ghana, some factors were taken in to consideration. In view of this it was necessary to get a clear picture of how GMO production will develop and what factors are influencing on it. The interviewed persons were asked to point out the most important factors influencing GMO production development in Ghana (Table 8).

Table 8. Factors influencing GMO production development in Ghana resulting from the survey*

Farmers ($n_1 = 8$)	Agricultural extension officers ($n_2 = 4$)
– education: on the benefits/threats of GMO production and GMO products – food scarcity – availability of GM seeds – supporting government policies – capital in terms of machines – ready market for the GMO produce – availability of land – provision of physical capital(funds)	– education: advocacy for GMO consumption from government – climate change – pests and disease outbreaks – famine
Agricultural researchers ($n_3 = 2$)	**Other actors in agriculture field* ($n_4 = 6$)**
– research and development – technology and knowledge transfer – consumer protection – farmers' access to inputs – institutional capacity for monitoring and quality assurance – government policies	– policies from government to support and begin GMO production – demand for GMO on the market – meeting labour requirement – education: public and farmers on the misconception of GMO – global competition

* The total number of participants of survey N = 20; other actors in agriculture field included agriculture lecturers as well as agriculture engineers

Source: The results of the authors' survey

The educational aspect is in two folds intensive education for farmers and consumers, which is the Ghanaian population (Table 8). First and foremost, farmers require extensive knowledge on the sense of GMO and what its contribution will be to the Ghana's agriculture as well as their on-harvest quantity. One of the key anti GMO group is Coalition for Farmers Rights and Advocacy (COFAG) [2022]. In a press statement released in 2014 concerning the plant breeders bill which was released in relation to GMO production it outlines the concerns of the farmers on the promoting GMO production, which can easily be solved with passing of information from Ministry of Food and Agriculture to the farmers [Nsafoah et al. 2011, Baffour-Awuah 2020].

The other aspect concerns the consumers of the GMO food. The demand for GMO products will depend on its level of consummation apart from the ones that will be exported. There are misconceptions about GM foods and it is generally seen to have adverse effect on human health although most of these view by the people has no scientific bases. Some of these unfounded views are related to GM foods causing cancer due to

the genetic altering [Kangmennaang 2016, Paliwal 2019]. This issue can be resolved by providing detail labelling of GMO products for consumers and also holding seminars in community centres to educate the general public; that GMO is the future of agriculture, which can help support the growing population. In addition, information can also be provided on the nutritious value of the GM foods [Rodriguez, Lee 2016]. The Ghanaian population lacks trust in the government to be able to adequately regulate GMO foods on the market through the Food and drugs Board Authority of Ghana [see also: Akinbo at al. 2021]. Moving forward, if the government is able to publicize the steps, they are taking into ensuring the safety of Ghanaians, consumption won't be an issue to deal with [Ampadu-Ameyaw et al. 2020, Baffour-Awuah 2020].

In the survey, policies by government was also one of the general factors cutting across. The actors in the agricultural field once again does not know the government has passed a regulation to cover, the introduction, import. export and handling of GM foods as well as the confined field trial. This can be found in the National Biosafety Act for 2011 [Opoku 2020].

According to the Food Sovereignty Ghana (FSG)[1], the country is in serious danger from the Plant Breeders' Bill adopted by the Ghanaian Parliament in late 2020 [Opoku 2021]. According to the FSG the bill is a give-away of agricultural heritage and agricultural future to western multinational corporations. In return, Ghana gets nothing but false and empty promises. The bill may eliminate jobs and create unemployment in Ghanaian agricultural areas. It will also require farmers to buy new seedlings every year and buy chemicals that are required for use with the seeds [Akinbo at al. 2021]. This will drive many farmers into debt. Burdened by debt, farmers are likely to lose their farms, and those working on farms will move to the cities, where there are no jobs to replace the lost farming jobs. Implementing GMO will make Ghana dependent on foreign corporations for seeds and foods and farmers will be forced to buy the limited variety of seeds available from multinational corporate plant breeders [FSG 2014].

Capital involving the distribution of GM seeds and funds and machinery to manage a GM driven farm. Opinions provided, if Ghana decided to go into commercialized farming, the Ministry of Food and Agriculture of Ghana should make the seeds available at all times to encourage farmers to move into production. In cases where the seeds are hard to obtain, the farmers will go back to their traditional farming to maintain their source of income. Once again just like in traditional farming, in conventional farming, machinery is of very high importance, because there will increase in yields and reduction of post-harvest loses. Due to this the availability of combine harvesters and the rest should be affordable to every farmer, in order not to waste money for production of food and latter leave it to perish due to lack of machinery and storage barns.

[1] The Food Sovereignty Ghana is a bottom-up movement of Ghanaian citizens dedicated to the promotion of food sovereignty in Ghana [FSG 2014].

Aside these opinions, there were some underlying factors as well which stood out in the options provided are global competition and climate change. Ghana's position on the world trade is on a fairly low to average performance for majority of agri-food produce side cocoa, which is the main cash crop, that fetches the country revenue. The country will be obliged to go into commercialize GM farming because of the growing competition on the world market [Opoku 2022]. Countries that have adopted GMO, are doing well in terms of production and revenue [Brookes, Bartfoot 2016]. In the coming future Ghana will have start GMO production in order to stay relevant on the world market with its exporters, and also neighbouring countries for major crops.

Climate change: being one of the factors, with the increasing nature of global warming, this is going to have an enormous impact on the seasonality of crop planting. In Ghana most rains are expected from June through to July in major areas. Aside the change of seasonal rains, the effect of warmer conditions, which are not favourable for some crops. GM seeds will be a big solution to drought, in case where rains cease, and irrigation system are inefficient, or their sources are dried up. Aside this with the growing population of the Country, going into GM production, will help provide food security and also prevent scarcity of food.

The ongoing policy-making process in Ghana about genetically modified organisms stems on the Plant Breeders' Bill of Ghana, of October 1, 2013. The main goal of this Bill is to establish a legal framework to protect the rights of breeders of new varieties of plants and to promote the breeding of new varieties of plants to improve the quantity, quality and cost of food, fuel, fibre and raw materials for industry. The ideas like biotechnology used for sustainable agriculture production and food security, policy decisions encouraging its future adoption are influenced by health, scientific, economic, environmental and political factors dictated by different ideologies, values and norms. While locally pioneered plant breeding is visible and common in the Ghanaian food chain, plant breeding or GMOs or biotechnology from international corporations is strongly resisted by anti-GMO coalitions. Understanding the nature of biotechnology policy-making is fundamental for future development of agricultural technology in Ghana [Braimah et al. 2017].

In working towards improving productivity in Ghana, the government has already tried a number of solutions, some of which include biotechnology, innovations in machinery, chemicals, agronomy and information uptake [Godfray et al. 2010]. This is very important for understanding the future of biotechnology in Ghana, as it draws attention to the opposition to GMO.

Because framers in Ghana struggle with the problem of lower crop yields, they are encouraged through government policy to intensify production by adopting improved technology [Ignatova 2015]. The following policies and programmes are the examples of such practices: the Ghana Poverty Reduction Strategy II, the Food and Agriculture Sector Development Policy, the Savannah Accelerated Development Authority and the

Ghana Commercial Agriculture Program [Braimah et al. 2017]. There are also private programmes, including the Agro-Dealer Development Program launched as part of the Alliance for a Green Revolution in Africa, supported by the Rockefeller and Bill and Melinda Gates Foundations [Butler 2010]. According to Hanson Nyantakyi-Frimpong and Rachel Bezner-Kerr [2015], about 2,400 agro-dealers were contracted to supply high-yielding seeds and fertilizers to farmers within this initiative. In areas of northern Ghana, high input use in hybrid maize production has become too expensive and labour demanding thereby negatively impacting food security among peasant farmers [Braimah et al. 2017].

In the midst of complaints regarding hybrid seed technology in Ghana by peasant farmers, the enactment of the Ghana's Biosafety Act of 2011 (Act 831) and recent attempts to pass the Plants Breeders' Bill, permitting the Centre for scientific and industrial research in Ghana to conduct trials of specific GMO's: Bt cowpea, rice, and cotton, Bt sweet potatoes[2], could not be tried due to late schedule, which Bt application has generated public debate. After this it was officially introduced in 2013. The Plant Breeders Act seeks to establish a legal framework to promote the breeding of new plant varieties and improve food production in Ghana, which the local seed developers though will have a tremendous impact on their activities, if the government chooses to import GMO seeds internationally for agriculture [Adenle 2014].

Anti GMO groups started emerging after the government of Ghana tried passing the plant breeder's bill. The initial spark of this antagonism was due to the fact that the local breeders felt enforcing the bill will result in the rights of multinationals being favoured at the expense of local farmers and breeders. Aside this debate, there are huge debate about the effect of GMO on the health of Ghanaians as well the environment. There are a number of anti GMO groups such as the Food Sovereignty Ghana, Coalition, Coalition for Farmers Rights and Advocacy, Peasant Farmers Association of Ghana and Vegetarian Association of Ghana [Braimah et al. 2017, Opoku 2020].

The effect on production factors; land, labour and capital depict that the Ghana will immerse benefits, if GMO production commences the benefits on land out weights the negative. This can lead to soil fertility management. The soil plays a vital role in crop production. The traits of GM crops like herbicide tolerance, insect resistant has helped to interpret how it supports and maintains soil fertility. For instance, the reduced use of herbicide greatly improves soil fertility and helps reduce the excessive use of fertilizer which also has adverse effect on the human health [Frimpong 2020].

Another phase of production factor is labour, which is an integral part of agriculture. Information gathered from the survey shows that conventional farming or GMO production will lead to both increase and decrease in labour depending on which section of farming

[2] *Bacillus thuringiensis* (Bt) crops are plants genetically engineered (modified) to contain the endospore (or crystal) toxins of the bacterium, Bt means to be resistant to certain insect pests [Abbas 2018].

the labourer is employed. Majority of part time labourers will lose their jobs, due to the increase in productivity, the use of machinery for harvesting is more ideal to be able avert post-harvest loses. This is because the main job of the part labourers was needed during harvest periods and also during planting seasons. To buttress this view also, there will be no need for manual spraying of herbicide amongst other fertilizer distribution activities. In the nutshell, GMO production goes hand in with mechanization, in order not to lose the harvest.

The future of GMO production in Ghana calls for investment in the capital factor; machinery and provision of funds to support farmers to purchase the seeds. The government in this space is tasked with making GMO production attractive to farmers by making capital readily available to prevent farmers from losing interest. GMO production in this area of production factors will needed a well-capitalized system to maintain its production.

Majority of Ghanaians have reservations about GMO consumption and production; most these concerns are mainly cantered on the benefits and threats [Buah 2011]. This section will juxtapose benefits and threats in the light of consumption and effect on the country. One of the most outstanding opinion derived is food security. One of the key goals in the Sustainable development goals is food security; zero hunger and nutritious food. This escalates down to sustainable agriculture, which in the space can only be achieved through biological innovations, in the light of GMO production. With the exponential increasing population of Ghana, GMO production is a must have to be able to achieve a zero hunger and nutritious food for the Country.

The future of GMO in Ghana is also largely linked to its performance on the world trade market. For the country to sustain positive trade balance; its imports of agriculture produce will have to reduce for the exports to be increased. This action calls for supplementing traditional farming with GMO production. This will go a long way to increase famers' income and also increase Ghana's revenue in agricultural trade on the world market. It will also make other crops have significance other than the cocoa production which is the main cash crop of the country.

Aside the key benefits, most of the information gathered on the threats of GMO is largely based on consumption. Majority of the population are very sceptical about consuming GMO foods [Baffour-Awuah 2020]. This is largely based on lack of extensive and intensive education on GMO crops and its related benefits. Most of the population believes the genetic alteration in the crops, can cause some health-related problems like cancer [Kangmennaang et al. 2016]. To guarantee the safety of Ghanaian consumers and also to ensure GMO production makes a reality in the shortest possible time, the government will have to provide education and also provide assurance for the population to effectively regulate GMO regulation to encourage them to purchase and consume the GMO foods.

CONCLUSIONS

Effective productivity can be earned through working production factors. Capital is the most lacking factor in agriculture production in aspects of mechanization, funds and basic access to farm supplements like seeds and fertilizers. The issue of land tenure is largely dominant having adverse effect of crop production, because of the restricted nature of having access to land. To resolve this the government should be able to increase budget allocation to enhance capital for the farmers. In lieu of this supplementing this with GMO production in the form of biological innovation will be of a tremendous impact, to aid farmers to increase yield per hectare as well as productivity.

With the current litigations with GMO production, the future of Ghana going actively in its production will be to provide a complete education on GMO production and consumption to encourage the Ghanaian farmers as well as population to patronize GMO. Because this will really cut down the expenditure for some capital factors like fertilizers.

Summarising the study has provided insight into:

1. Ghana needs to improve in all three areas of production factors, especially capital. From the relationships obtained, it shows how scarce machinery are to farmers which affects their harvesting periods leading to post harvest losses.
2. Additionally, still in the area of capital, although the use of pesticides has been given a fair attention in agriculture. Minimizing its usage and employing GMO will be of absolute essence. The use of GM seeds will be of much help to reduce the use of pesticides which is now found to be a threat to human health.
3. The major roadblock to Ghana fast forwarding the implementation of GMO production is lack of intensive and extensive education to both the farmers and public. Looking at the current situation, it will take Ghana quite a number of years to implement its production, with all the current litigations going on in the country.

The authors of the study are aware of the limitations of the sample size of questionnaire survey we conducted and we would like to acknowledge that the questionnaire survey was planned much broader. The questionnaires were sent to much more farmers, agricultural extension officers, researchers, government officials, politicians and other actors, but the Covid-19 pandemic thwarted the plans of researchers and we received only 20 responses, and some of them were incomplete. Because of the fact the sample size is small, it was difficult to present data in proper way and find significant relationships from the data, as statistical tests normally require a larger sample size to ensure a representative distribution of the population and to be considered representative of groups of people we interviewed. Nevertheless, we decided to include some opinions of the experts and treat them as a supplement of the literature analysis. The authors of the manuscript would like to underline that the topic of GMO is actual and very important in present and future development of agriculture in Ghana and it requires further in-depth research.

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CZYNNIKI PRODUKCJI ROLNICZEJ A MOŻLIWOŚCI PRODUKCJI GMO W GHANIE

Słowa kluczowe: organizmy modyfikowane genetycznie (GMO), czynniki produkcji, ziemia, praca, kapitał, produktywność, produkcja rolnicza, Ghana

ABSTRAKT

Celem głównym artykułu było wskazanie czynnika lub czynników limitujących produkcję rolniczą w Ghanie. Ważne było również określenie znaczenia organizmów genetycznie modyfikowanych w doposażaniu rolnictwa w czynniki produkcji. W literaturze przedmiotu przedstawiano różne poglądy na temat tego, które czynniki produkcji odgrywają kluczową rolę w rolnictwie. Jednak, ziemia, praca i kapitał pozostają najistotniejszymi czynnikami produkcji w rolnictwie. W Ghanie, podobnie jak w innych państwach, wykorzystuje się te same czynniki produkcji, ale w rolnictwie tego kraju cały czas istnieje problem ich niskiej produktywności. Organizmy genetycznie modyfikowane traktuje się jako czynnik innowacji biologicznych w rolnictwie, a jednocześnie uzupełnienie czynników produkcji. Na podstawie analiz przeprowadzonych w pracy stwierdzono, że czynnikiem ograniczającym w rolnictwie Ghany jest kapitał. Istnieje więc pilna potrzeba poprawy wyposażenia rolnictwa w kapitał. Istotną rolę mogą tu odegrać organizmy genetycznie modyfikowane, których znaczenie i upowszechnienie w produkcji rolniczej na świecie jest coraz większe.

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