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Mango Growing Potential of Ghana: Modelling Of Suitable Land Areas within Ghana's Agro-Ecological Zones for Mango Production

[1&2]Nettey S. N. A, [2]Agodzo S. K., [3]Fialor. S.C, [4]Marx W. [1&5]Asare D. K1,[6]Loh S.K
[1]Biotechnology and Nuclear Agriculture Research Institute (BNARI) of Ghana Atomic Energy Commission, P. O. Box LG80, Legon-Accra, GHANA, [2,3] Department of Agricultural Engineering, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi GHANA, [4]Departments of Hydraulic Engineering and Water Resources Management, University of Stuttgart, Germany, [5]United States Agency for International Development - West Africa - Analytical Support Services and Evaluation for Sustainable Systems (ASSESS) Project, Accra, Ghana
[1&2]samstut@yahoo.com, [2]skagodzo7@usa.net, [3]simonfialor@yahoo.com, [4]walter.marx@marxuwa.de,
[1&5]daniel_asare@yahoo.com [6]loeyramkofi@gmail.com

Abstract— **Revenue generation from the cultivation and distribution of mango has increased over the past two decades across Sub-Saharan Africa. Experts say Ghana has the prerequisite conditions for making mango her next "gold mine". This research project therefore sought to model mango production potential of Ghana by delineating suitable areas. This will enable stakeholders to contribute meaningfully to efforts being made to convert Ghana's comparative advantage in mango cultivation into a competitive one. By superimposing the ArcGIS modelled outputs (maps), a resultant map was obtained which gave an overview of the potential locations within the respective agro-ecological zones (AEZs) with varying suitability ratings (SR) ranging from 1 (least suitable) to 10 (most suitable). Areas within the Coastal Savannah Zone (CSZ), Guinea Savannah Zone (GSZ) and the Transitional Zone (TZ) where commercial mango growing activities are known to occur could be located within this resultant map. The sum of cultivable areas (ha) with each of the 3 resulting suitability ratings; SR 2, SR 5 and SR 10 were 1,429,682 ha, 15,059,000 ha and 6,396,710 ha representing 5.9 %, 63.1 % and 26.8 % of the total land area of Ghana respectively.**

Keywords: Modelling, delineate, mango, map model and suitability ratings.

I. Introduction

One important fresh fruit from Sub-Saharan Africa which is performing well on the World market is mango. Mango (Mangiferaindica L.) is a member of the Anacardiceae family, Bally, 2006). According to Eurostat 1998 a and b, fresh vegetables export from the Sub-Saharan region to industrialized countries during the period 1989-1997 recorded growth of 150 %. South Africa, Cote d'Ivoire, and Kenya are playing leading roles in the export of non-traditional crops to markets of the industrialized countries (Singh, 2002). In Table 1 however, Ghana's mango exports into Europe is ranked 25th in 2011 in terms of volumes, far behind Cote d'Ivoire and Senegal which ranked 5th and 9th respectively.

Though Ghana's horticultural industry has two mango seasons in most parts of the country, her mango yield records had been woefully inadequate for her to compete meaningfully on the international market for fresh fruits and vegetables. This might be due to stunted attention over the years received towards the call for infrastructure development for its large scale production. According to Hatsu (2006), mango cultivation is one area within the horticultural sector of Ghana's agricultural sector which, if well developed and provided with the necessary logistics and support, could easily make Ghana, its top exporter. In addition, only six varieties (Kent, Keitt, Haden, Tommy Atkins, Palmer and Zill) out of about forty one known species in the Anacardiaceous family are cultivated in Ghana, with nursery centres at Dodowa, Kintampo and Ejura (Ganry et. al., 2007).

Generally, countries with good climatic conditions have the niche to meet the ever-increasing demand of fresh fruits in industrialized countries at a more competitive price. This prompts the thnking that Ghana has not made the most out of her valuable land and climatic conditions. According to FAO (2005), out of the six agro-ecological zones, only two (i.e. Guinea savannah and Transition zone) contribute towards cash crop production, in addition to annual food and livestock with less strives for none-traditional cash crops (as indicated in Table 2). The rain forest and deciduous forest also support forest and tree crop plantation activities whiles the land use system of the rest are dominant with annual food crops and livestock. Additionally, commercial mango plantations and small holder mango farms are limited to a few areas such as Tolon-Kumbugu and Savelugu-Nanton in the Guinea savanna zone, Yilo Krobo, Manya Krobo, Akwapim South, Asuogyaman, Dangme West, North and South Tongu and Ketu in the coastal savanna zone and Ho, Hohoe, Kpando, Techiman, Wenchi, Kintampo, Nkoranza, Atebubu, Ejura Sekyeredumasi, Sekyere West in the Forest-transitional zone.

Experts views on Ghana‘s comparative advantage in the mango export business is great and untapped. The main objective of this research was, therefore, to model the mango production potentials within the agro-ecological zones of Ghana. The specific objective was to model delineated areas within the country where mango growing activities could potentially be undertaken using available climatic, soil, topography and land-cover information.

II. METHODOLOGY

To formulate the map-models used to study the mango growing potential of Ghana, the following data sets were acquired from the Ghana Meteorological Agency and the Centre for Remote Sensing and Geographical Information Services (CERSGIS) at the University of Ghana, Legon: (i) climatic parameters (temperature (oC), rainfall (mm), sunshine (hr), relative humidity (%) and wind-speed (km/d), (ii) soil quality parameters (soil depth, soil pan, soil drainage, soil electrical conductivity (EC), and soil texture, (iii) land use/cover of Ghana and (iv) elevation profiles of Ghana. The respective monthly mean values processed for the thirty (30) years (1982 to 2011) records of the climatic variables obtained from 21 synoptic weather stations in Ghana are presented in Table 1. In addition, details of a portion of the selected soil quality parameters, land cover parameters and elevation profile of Ghana, acquired were in shape file format. These data sets were grouped into classes using the author's suitability rating scale, a number coding formulated in accordance to literature and/or perceived levels of suitability for mango production, as shown in Table 4, 5 and 6. The various classes were also assigned colour codes to help their visual distinction in the GIS platform. For the data set on land cover profile of Ghana, areas unsuitable for mango plantations such as water bodies, roads, and electric grid lines, among others were considered to be restricted areas.

The ArcGIS version 10.1 software was used for data analysis and for the formulation of the map models. In this software, the resultant data sets were converted into raster format in the order shown in Figure 1 and then into "vector file" which allowed super-imposition of the various parameters on each other by assigning weights as perceived levels of suitability for mango production.

The variables were imported using the "Modelbuilder tool", weighted using Weighted Overlay tool, and executed to generate the executable maps. For areas unsuitable for mango plantations such as water bodies, roads, and electric grid lines, among others were assigned as restricted areas using the said Modelbuilder tool. This also employs the interpolation techniques to superimpose the output of sub-models on each other. This tool also employs the interpolation techniques to superimpose the output of sub-models on each other. This interpolation technique is within the Geo-statistical analyst tool in ArcGIS 10.1 within which lies an Inverse Distance Weightings (IDW) sub-tool. The map models were derived using ArcGIS model-builders' Overlay analysis tool. The tool combines the following three steps (ArcGIS help):

(i) firstly, it reclassifies values in the input rasters into a common evaluation scale of suitability or preference, risk, or some similarly unifying scale. (ii) secondly, it multiplies the cell values of each input raster by the raster's weight of importance, and (iii) finally, it adds the resulting cell values together to produce the output raster. Figures 2 shows the stages used to overlay the various data sets and super-impose the various outputs of the natural resource elements on each other to form a one great output.

Due to the unavailability of a more current geo-referencing data for the agro-ecological zones of Ghana as of the time of this study, the conclusions arrived through the interpretation of these modelled maps needs to be treated with caution.

Table 1 EU-27 Mango Imports Between 2006 and 2011 (in tons)

Ranking 2011	Partners	Period					Growth		Jan - Nov
		2006	**2007**	**2008**	**2009**	**2010**	**Annual**	**Total**	**2011**
1	Brazil	85,117	83,025	96,870	80,821	92,256	2%	8%	73,709
2	Peru	41,040	36,854	50,756	36,270	60,386	10%	47%	68,232
3	Israel	11,353	15,018	12,743	12,998	10,700	-1%	-6%	13,997
4	Pakistan	10,120	13,225	12,942	12,916	10,596	1%	5%	11,738
5	Cote d'Ivoire	14,433	14,706	11,249	11,701	11,323	-6%	-22%	9,768
6	USA	5,971	7,404	7,516	5,535	4,744	-6%	-21%	8,475
7	Costa Rica	7,549	4,664	5,360	5,685	3,429	-18%	-55%	6,873
8	Dominican Rep.	1,618	2,767	4,307	4,186	4,303	28%	166%	6,345
9	Senegal	6,194	4,702	6,034	6,240	2,758	-18%	-55%	5,338
10	Mexico	1,765	2,680	1,674	1,59	4,938	29%	180%	5,254
12	Burkina Faso	2,153	3,191	2,406	1,988	3,302	11%	53%	2,081
13	Mali	3,477	4,317	4,902	3,480	3,672	1%	6%	1,781
14	Gambia	785	857	696	1,246	776	0%	-1%	1,503
25	Ghana	295	983	1,097	880	428	10%	45%	197
31	Guinea	346	469	544	388	842	25%	144%	93
	Others	19,149	16,539	11,888	12,788	10,539	-14%	-45%	10,513
	Total	211,365	211,401	230,982	198,717	224,991	2%	6%	225,896

Source: Zakari (2012)

Table 2 Characteristics of Agro-Ecological Zones in Ghana

Zone	Rainfall/yr	Portion of cultivated area (%)	Length of growing season (Days)	Dominant land use system	Main food Crops
Rain forest	2200	3	Major season: 150-160 Minor season: 100	forest, plantations	roots, plantain
Deciduous Forest	1500	3	Major season: 150-160 Minor season: 90	forest, plantations	roots, plantain
Transition Zone	1300	28	-	annual food and cash crops	maize, roots, plantain
Guinea savannah	1100	63	180-200	annual food and cash crops, livestock	sorghum, maize
Sudan savannah	1000	1	150-160	annual food crops, livestock	millet, sorghum, cowpea
Coastal savannah	800	2	Major season: 100-110 Minor season: 50	annual food crops	roots, maize

Source: FAO, (2005)

Table 3 Plotted Means of a 30 Year-Period Meteorological Data

Towns	**Rainfall (mm)**	**Temp (Tmin)**	**Temp (Tmax)**	**Temp_avr**	**Wind speed (kts)**	**RH @0600**	**RH @ 1500**	**RH_avr**	**Sunshine (hrs)**
Wa	1012.23	22.8	33.79	28.3	2.4	71.6	44.1	57.85	6.2
Wenchi	1249.08	21.55	31.26	26.41	2.10	88.7	57.4	73.05	5.5
Navrongo	989.00	22.95	35.19	29.07	2.1	68.9	40.6	54.75	7.8
Bole	1096.40	21.1	33.17	27.14	2	83.1	49.6	66.35	6.8
Akuse	1046.20	23.2	33.27	28.24	2.4	93.1	60.9	77	5.8
Tamale	1086.90	22.78	34.37	28.58	3.1	75.9	45	60.45	7
Kete Krachi	1358.40	23.4	32.87	28.14	1.8	90	55.2	72.35	63
Ho	1270.31	23	32.42	27.71	1.5	92.8	59.6	76.2	7.2
Yendi	1167.20	22.3	34	28.15	2	77.2	46.6	61.9	6.7
Akatsi	913.06	23.66	32.18	27.92	2	95.24	66.41	80.825	5.5
Sefwi Bekwai	1403.44	22.6	32.72	27.66	1	92.7	59.91	76.305	5.4
Kumasi	1323.21	22.1	31.36	26.73	2.9	93.1	59.3	76.2	5.2
Oda	1410.10	22.4	31.73	27.07	1.5	94.9	64.7	79.8	5.2
Takoradi	1066.44	23.4	30.32	26.86	3.2	95.7	77.18	86.44	5.7
Koforidua	1307.20	22.1	32.1	27.1	1.7	93.9	63.12	78.51	5.8
Axim	1899.42	23.9	29.57	26.74	2.5	90.6	75.6	83.1	6.3
Ada	808.98	25.12	31.35	28.24	4.5	92.86	79.26	86.06	6
Accra	752.55	24.04	31.15	27.6	6.3	92.98	81.2	87.09	6.4
Saltpond	938.25	23.38	29.65	26.52	2.8	96.49	78.73	87.61	6.5
Tema	662.15	24.61	30.06	27.34	3.70	90.91	76.15	83.53	7
Abetifi	1287.99	22.47	28.51	25.49	3.40	91.6	65.26	78.43	7.5
Sunyani	1184.37	21.36	31.28	26.32	3.00	92.58	57.95	75.265	7.1

Avr = Average; RH = Relative Humidity; Temp = Temperare Source: Acquired data from Ghana Meterological Agency

Table 4 Ranked Values of Climatic Data Set, Done According to Perceived Level of Suitability for Mango Growth

Suitability Ranking (SR)	**Most Suitable 10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**Least Suitable 1**
Colour Classification										
T_{av}	> 36	36-32.5	32.5 - 29	29 - 25.5	25.5 - 22	22 - 18.5	18.5 - 15.0	15.0 - 11.5	11.5 - 8.0	8.0 >
Rainfall$_{Av}$ (mm)	< 660	660 - 817.4	817.4-974.8	974.8-1132.2	1132.2 - 1289.6	1289.6 - 1447	1447 - 1604.4	1604.4 - 1761.8	1761.8 - 1919.2	1919.2 <
Wind Speed (hrs)	< 1	1 - 1.8	1.8 - 2.6	2.6 - 3.4	3.4 - 4.2	4.2 - 5	5 - 5.8	5.8 - 6.4	6.4 - 7.2	7.2 <
RH av	< 40	40 - 47.5	47.5 - 55.0	55.0 - 62.5	62.5 - 70.0	70.0 - 77.5	77.5 - 85.0	85.0 - 92.5	92.5 - 100	100 <
Sunshine	> 7.8	7.8 - 7.475	7.475 - 7.15	7.15 - 6.825	6.825 - 6.5	6.5 - 6.175	6.175 - 5.85	5.85 - 5.525	5.525 - 5.2	5.2 >

Table 5 Ranked Values of Elevation (Altitude) According to Perceived Level of Suitability for Mango Growth

Suitability Ranking (SR)	**Most Suitable 10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**Least Suitable 1**
Colour Classification										
Elevation Classification (m)	< 100	100 - 200	200 - 300	300 - 450	450 - 600	600 - 700	700 - 750	750 - 800	800 - 850	850 - 900

Table 6 Ranked Values of Soil Quality Parameters According to Perceived Level of Suitability for Mango Growth

	Most Suitable 10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**Least Suitable 1**
Colour										
Soil EC	<0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	> 0.8
Soil Drainage	Well					Mod. Well				Poor
Soil Iron Pan	Non-Pan									Pan
Soil Texture	Light (< 25% clay)					Medium (50% Clay)				Heavy (100% Clay)
Soil Depth (cm)	>100	90	80	70	60	50	40	30	20	<10

Source: Author

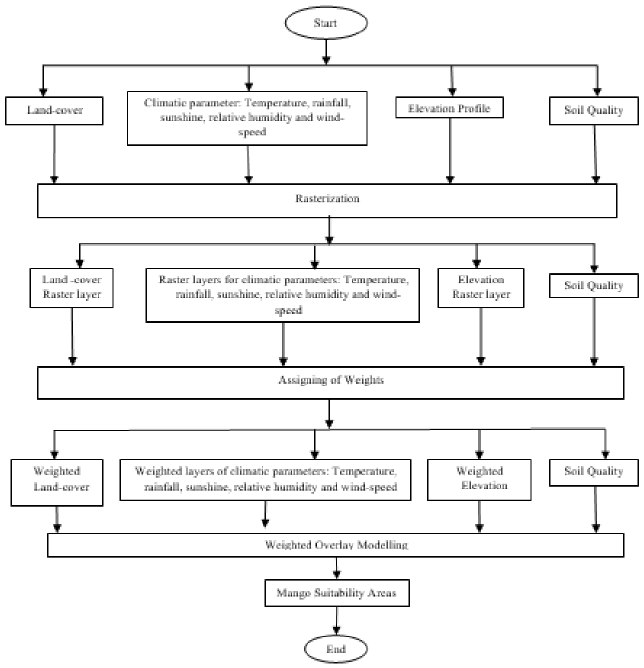

Figure 1. Workflow for modelling suitable areas for mango production using ArcGIS 10.1.

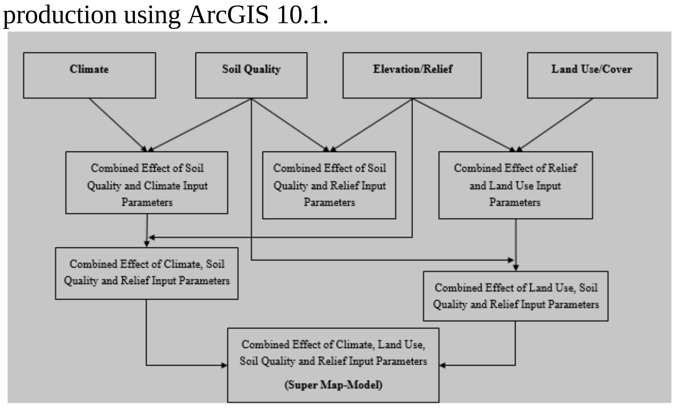

Figure 2. Schematic diagram for modelling data set (Soil Quality, Climate, Elevation/Relief and Land Use) combinations.

III. RESULTS AND DISCUSSION

Sub-map models made to help delineate potential areas in Ghana that could be suitable for commercial mango production were as shown in Figures 3 - 8. To appreciate the varying impacts that each considered input parameter made on the delieanation process, these maps were superimposed on the Agro-Ecological Zones (AEZs) of the country.

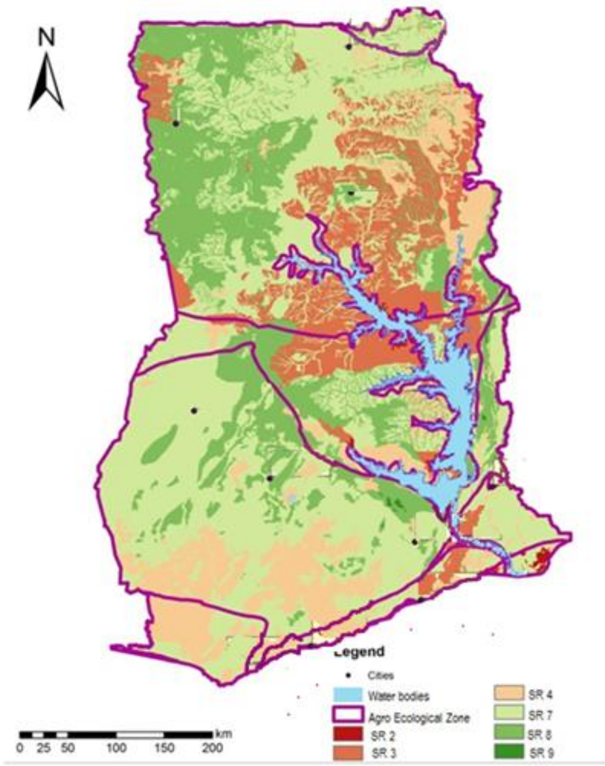

Figure 3. Suitability map for mango production based on elevation and soil quality parameters.

Figure 3 shows the suitability map-model for mango production with regards to soil quality and relief/elevation considerations only. In general, mango orchards need well drained and fairly deep soils (about a meter) with a moderate texture and a non-pan soil profile formation to thrive well.

The measure of electrical conductivity (EC) shows the level of Na+ and Cl– ions in soil mediums. Yahia (1999) had also reported that a mango could thrive in growth mediums with EC values ranging between 4 and 6 ds/m. Like other crops, mango growth rate and reproductive performances are hampered when planted in highly saline soils. Also, elevated locations are more ideal for mango cultivation but areas with steep gradients are prone to erosion and excessive drainage. In areas/locations with steep gradients, soil moisture quickly gets depleted and as such frequent irrigation interventions are required which raises the cost of production. Additionally, low-lying areas are likely to be swampy as their water table will be quite high, a condition not ideal for mango production. The combined effects of soil quality and elevation as used in this sub-model, record a suitability rating of between SR 7 and SR 9. An area such as the Keta Lagoon basin as shown in Figure 3, recorded a very low suitability rating of SR 2. This might be due to both the high EC of soils and the low-lying nature of this locality.

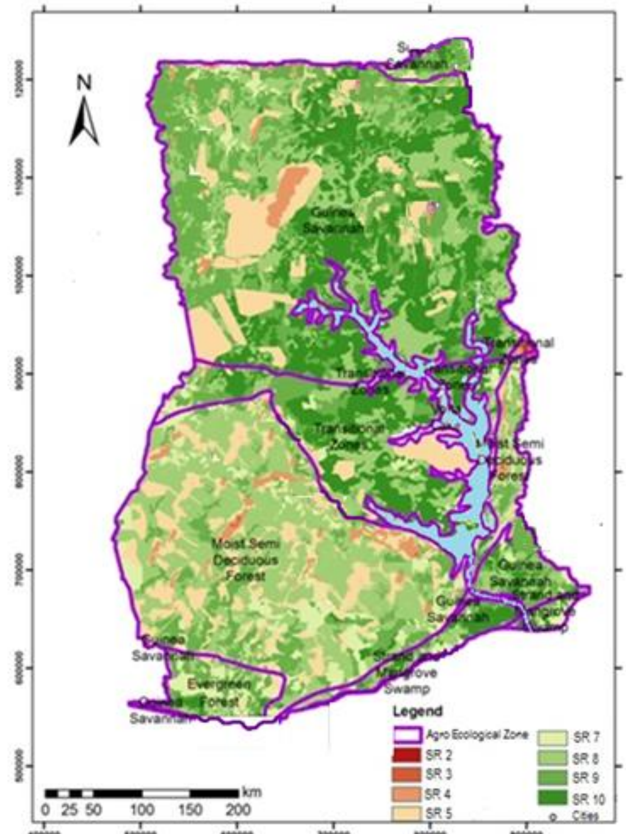

Figure 4. Suitability map for mango production based on land cover and elevation parameters.

A portion of the north-eastern part of the forest-savannah transitional zone and the south-eastern part of the Guinea savannah zone recorded low suitability rating of SR 3, which might mainly be due to the presence of "pan formation" within the soil profile.

With regards to the combined effects of land use/cover and elevation data, the delineation of locations within the country, where mango production is suitable, was made possible (Figure 4). Land use such as those within the Land use data including "urban settlements, peri-urban, town, international airport, beach, salt winning, river, reservoir (dam), lake, lagoon, tree crop plantation (oil palm, coconut, and rubber), non-tree (rain-fed) mono-cropping (maize), mixed bush fallow cropping (short fallow) among others" (as preserved by the Forestry Commission of Ghana) combined with the elevation/relief data of Ghana, showed that there are locations within the country with very low (SR 2), quite low (SR 3) and slightly low (SR 4) suitability ratings for mango production. Most locations in the country, according to the sub-map model, however, indicated appreciable ratings of between SR 7 and SR 10.

Additionally, the combined effects of all soil quality and climate parameters considered under this study resulted in the sub-map-model in Figure 5, which have a general suitability rating of extremely suitable (SR 10) and an average suitability rating of SR 5.

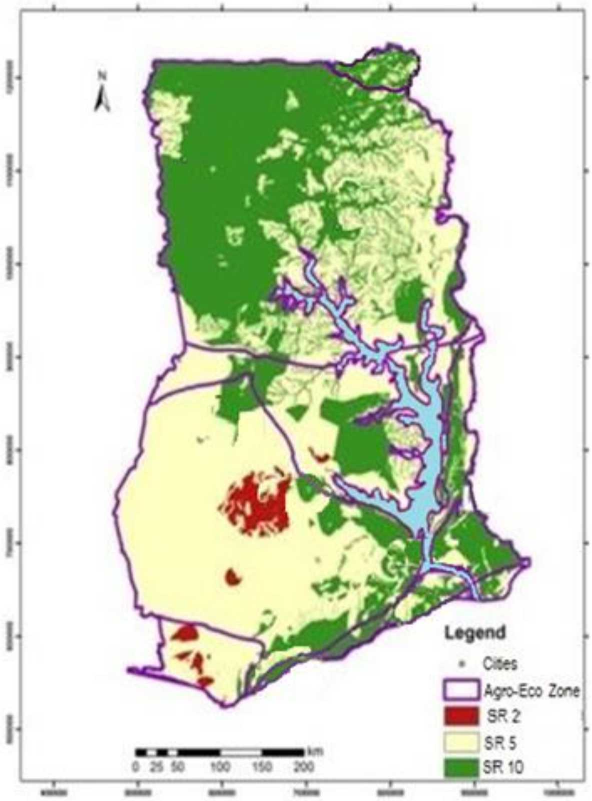

Figure 5 Suitability Map for Mango Production based on Soil Quality and Climatic Parameters

Locations within this sub-map model with a very low suitability rating of SR 2 could be said to be minimal. Almost all locations within the Sudan savannah, Guinea savannah, forest-savannah transitional zone and the Coastal savannah have been depicted by the sub-map model to have high suitability ratings between SR5 and SR 10, for mango production. Thus, this map-model captures all the most known mango growing areas in Ghana which have high suitability ratings. In addition, areas ranked SR 2 (low suitability rating) not known to be major mango growing areas in Ghana are also captured by the sub-map model.

Superimposition of the land cover sub-map model onto the soil and elevation sub-map models to identify potential areas within the various AEZ where large scale mango plantations could be raised were is shown in Figure 6. The resulting sub-map model indicates that almost the same land space has a suitability rating of SR 4, SR 7 and/or better for mango production.

Figure 6. Suitability map for mango production based on land use/cover, elevation and soil quality parameters.

The Rain forest zone and the Semi-deciduous zones have been delineated by this sub-map model to have unfavourable suitability ratings (SR 2 and SR 3) for mango production. A number of locations in these zones are already noted to be hosting tree crops plantation such as oil palm, rubber, cocoa and coconut.

It was also noticed in Figure 7 that the superimposition of "elevation" on the model output in Figure 5 impacted on the total suitable land area that had been rated as "SR 10" (high suitability rating) for mango production but at the same time increased the land area with SR 2 rating (low suitability), whiles decreasing areas with SR 5 suitability rating. These were due to the effects of slopes, hills and depressions where mango production is a challenge. Also, the size of land area with suitability rating SR 5 increased relatively in this modelled output. This could assert the fact that areas of high elevations have a decreasing potential for mango orchard establishment.

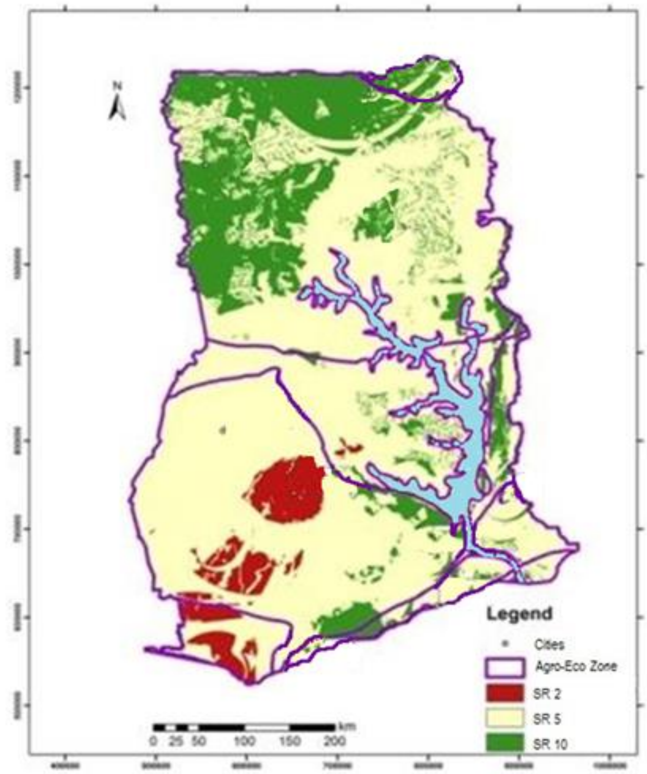

Figure 7 Suitability map for mango production based on elevation, soil quality and climate parameters.

However, the Coastal savannah zone, Sudan savannah and Guinea savannah zones were all delineated as favourable with high suitability ratings for mango production in contrast to the rain (evergreen) forest and a portion of the Deciduous forest zones. Both the Forest-savannah transitional and the deciduous forest zones, however, recorded locations with three different suitability ratings for mango production.

Without the consideration of possible effect that land use pattern could have had on the delineated output in Figure 5, it could not be said to depict an appreciable level of reality. It must however be noted that, areas such as those with water bodies and/or those earmarked for various purposes are also included in this output model. This buttresses the need to investigate what the effect of "land use" could have on Figure5.

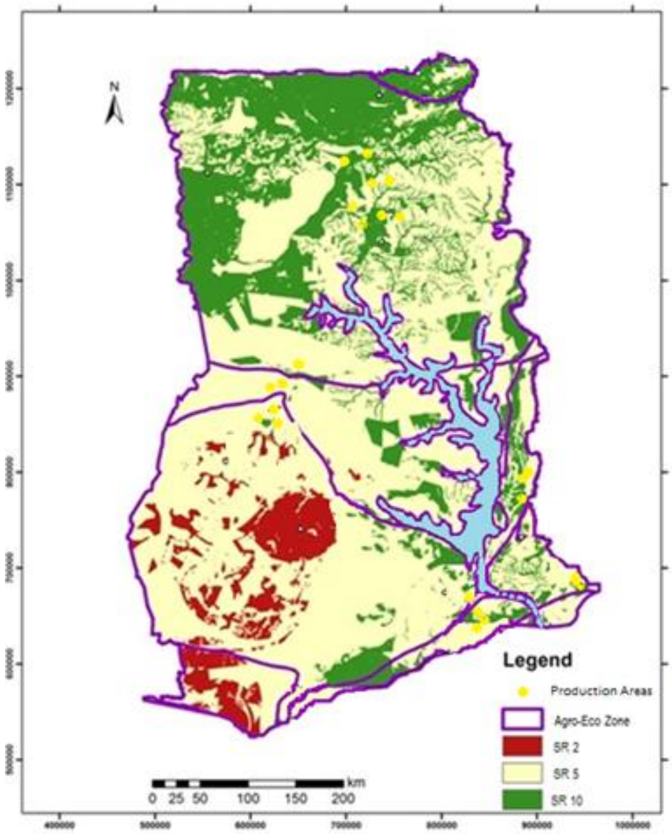

Figure 8. Suitability map for mango production based on land cover, elevation, soil quality and climate parameters showing some known mango production areas.

The potential areas within the respective AEZs where mango production activities can or cannot be suitable was simulated by superimposing the sub-map model on land use pattern onto Figure 7. The resulting output in Figure 8 indicated that mango plantation will not do so well in some locations within Semi-deciduous and Rain forest AEZs as the suitability ratings were SR 2 and SR 5.

Areas within this "super" map-model with suitability ratings of SR 5 and SR 10 are within the Coastal savannah zone, Guinea savannah zone and the Forest-savannah transitional zone. Though the Forest savannah transitional zone has locations with suitability rating of SR 2, the area covered occupy a very small portion of the total suitable areas for mango production.

The total cultivable areas (m2) estimated for each of the classifications using the computational tool within ArcGIS version 10.1 were as given in the Table 7.

Table 7 Estimated mango cultivable land areas delineated

Suitability Rating	**SR 2 low suitability**	**SR 5 moderate suitability**	**SR 10 high suitability**
Agricultural Land Area (m^2)	14,296,820,400	150,590,000,000	63,967,104,000
Equivalent in Hectares (ha)	1,429,682	15,059,000	6,396,710
% Suitability Area to Total Land Area of Ghana	5.99	63.13	26.81

Notwithstanding the fact that numerous crops could be listed under the crop sub-sector of Ghana's agricultural economy, information provided in Table 7 implies that nearly 89.94 % of Ghana's land area has moderate to high suitability for the production of mango in commercial quantity, for both the local and export markets.

5 Conclusion and Recommendation

In conclusion, having considered a wide range of soil quality parameters, climatic parameters, elevation profile and land cover patterns of Ghana, 26.8 % of the suitable areas for mango production delineated were highly suitable (rated SR 10), 63.1 % were moderately suitable (rated SR 5) and 54.0 % were of low suitability (rated SR 2). In contrast, the soil suitability map indicated that over 90% of Ghana's soil cover will potentially support mango growing activities. Furthermore, combing soil quality and elevation parameters, areas within the country with less suitability ranking for mango production were identified to be locations with water bodies, mountainous regions, depressions and locations where hard-pans were identified beneath the soil sub-surfaces.

The impact of land use pattern on the combined effect of soil quality and elevation was profound. Findings from the above showed that most locations with low suitability ratings (SR 2 and SR 3) were mainly at the South-western part of the country (Rain forest zone and the Semi-deciduous zone) though a few of these ranked locations were also found distributed in other AEZs. In contrast, a large portion of locations within Ghana scored mango growing suitability ranking of between SR 5 and SR 10.

Climate is one of the most important factors that control agriculture in general and hence its effects is of great concern to policy makers and stake-holders alike. Within the constraints of available data, the map-model output on climate indicated that Ghana has the requisite climatic conditions for large scale mango cultivation since her land areas were of SR 5 and SR 10 suitability rankings. Notwithstanding this, there are areas within the country where local conditions of either rainfall or temperature do not support mango production. Notable among such areas is Axim locality where rainfall amounts are high, temperatures are low and relative humidity is also high. Under these conditions, the mango trees do not flower and even if they do, the fruits are disease-prone and therefore, it is not economically viable to produce mango on a large scale.

Having considered all the elemental factors used to obtain the "super map-model", it could be concluded that mango plantations will do very well in the Coastal savannah, Sudan savannah, forest savannah transitional and the Guinea savannah zones than in relatively smaller areas that fall within the Semi-deciduous and Rain forest zones of Ghana's AEZ. Consequently, Ghana has a niche potential (with regard to the nature of her climate, soil quality, elevation and land cover parameters) for large scale production of mango fruits for both local and foreign markets.

It is recommended that the government agencies responsible for agricultural land use must formulate policies that will entice traditional rulers, local governments and individual land owners to apportion significant amounts of land resources for the production and promotion of non-traditional cash crops, including mango. This will help attain and sustain the production levels of mango and export targets set by the Ghana Export Promotion Council (GEPC).

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