A SURVEY AND ANALYSIS OF THE EFFECTS OF RIVER POLLUTION ON FLOODPLAIN AGRICULTURE IN GHANA: A CASE STUDY OF RIVER PRA

Isaac Boateng, Ellen Kwarteng, Kofi Adu-Boahen, Ghana

Key words: floodplains Agriculture, Crop potential, River Pra, Heavy Metals

SUMMARY

Agriculture has been known to be the backbone of countries worldwide, of which Ghana is no exception. Floodplain farming is of much importance to most Ghanaian farmers residing along major rivers in the country. Alluvial soils have been classified as having a nutrient composition in their right proportion to boost crop production along river floodplains. This study, therefore, assessed crop production and agricultural development along the Pra River floodplain. The specific objectives for the study were to analyse the growth potentials of crops within the floodplains under study and the assimilation of heavy metals by these crops. The study was conducted along the Pra River floodplain at the Daboase- Beposo stretch. Three crop samples (maize, okra, cowpea) were collected along the river at different intervals concerning the proximity to the river. A 14ft by 30ft land was acquired to cultivate crops to know their morphological trait in the floodplain. The study revealed that nutrient composition in the alluvial soil was low with high acidity content. Crops planted along the floodplain exhibited a low level of nutrient composition and high acidity level in the soil.

A SURVEY AND ANALYSIS OF THE EFFECTS OF RIVER POLLUTION ON FLOODPLAIN AGRICULTURAL IN GHANA: A CASE STUDY OF PRA RIVER

Ellen Kwarteng, Isaac Boateng, Kofi Adu-Boahen, Ghana

1.0.INTRODUCTION

Anthropogenic activities such as mining and farming have led to the introduction of heavy metals (Arsenic, Lead, Cadmium and Mercury) in soils and water bodies. This has directly affected crops planted in such places. Kumar, Soo, Zhang, Fai and Kim (2019) commented that heavy metals have led to unanticipated toxins in crops which have also affected food security in several parts of the world. This is because heavy metals affect the microbial component of soil. The presences of these toxic substances lead to the browning of root tips and reduced photosynthesis, nitrogen deficiency, necrosis, leaf roll and chlorosis in crops (Jamal, Khan, Munir and Anees, 2013; Ohanmu and Ikhajiagbe, 2018). Also, such polluted soil negatively affects plant growth, yield and performance (Chibuike and Obiora, 2014).

According to Ohanmu and Ikhajiagbe (2018), heavy metals slow down plant metabolism. Heavy metals produce contaminated crops which is harmful to human health such as cancer (Ailenokhuoria and Omolekan, 2019). In soils, heavy metals are accumulated through various sources and practices such as using excessive agrochemicals, other chemicals for mining, untreated sewage, industrial effluents and geological cycle (Jamal et al., 2013). Again, the presence of heavy metals in plants is often regulated by factors such as plant species, soil features, irrigation characteristics, fertilization and the relationship that exist among these factors (Lu, Yao, Shan, Jiang, Zhang and Yang, 2015). Nonetheless, the use of indigenous fertilizers such as sheep manure reduced the concentration of heavy metals in soil and crops (Ma, Chen, Antoniads, Wang, Huang and Tian, 2020). The degree of heavy metals varies among plants and at different parts of the plants (Ailenokhuoria and Omolekan, 2019). For this study, the assimilation of heavy metals on maize, cowpea and okra was considered.

Floodplains are one of the important areas for farming due to the fertile alluvial soil provided by the rivers. Beilfuss (2002), who researched on the Zambezi River, found that in the wet season there are two cropping periods. During the rainy season, the fertile alluviums adjacent to the river channel are planted with crops of cereals, legumes, and gourds that are harvested just before the river's expected annual flood. These crops use rainwater for their growth. Farmers plant a second crop on the alluvial soils after the floodwaters begin to recede, sowing seeds just behind the retreating water line and harvesting at the end of the dry season (Beilfuss, 2002). The floods also recharge local aquifers that provide an essential source of groundwater during the dry season (Beilfuss, 2002).

The rate of environmental pollution in Ghana has been on the ascendency over the years (Boateng et al, 2020; Anim-Gyampo, Kumi, & Zango, 2013; Nyarko, 2001). A major aspect of environmental pollution in Ghana is related to the activities of illegal mining in the country. As a result of mining activities in the country, water bodies are known to be the most affected in areas where illegal mining (Galamsey) are being practised (Duncan, 2020; Banchirigah, 2008). They usually practice open surface mining and use the water bodies as a medium to mine more minerals. In the process of mining in these areas, certain metals like mercury, lead, arsenic, cadmium and so on are used. Unapproved mining practices in and along water bodies has caused the water bodies to be polluted by these heavy metals.

In Ghana, most farmers have their farms along the floodplains of a major river in the country. The Pra River has been observed to be under threat due to inappropriate mining methods along the river (Dorleku, et al, 2018). As a result of this, the whole nature of the Pra River has been observed to be altered over the years. The presence of heavy metals in the Pra River is accumulated in the soils along the river. The presence of these metals in the soils is further assimilated by the crops being cultivated along the river floodplain. In the long run, human beings are exposed to these metals through the intake of these crops that are cultivated along the floodplain through the food chain. The Food and Agricultural Organization (FAO) and World Health Organization (WHO) (2011), as well as the United States Environmental Protection Agency (US EPA) (2007), have elucidated the harmful effects of these heavy metals on human health and threat to the whole ecosystem.

Also, during the inappropriate mining methods used by companies along the Pra River, the river has been exposed to certain chemicals which in effect affect the quality of the soil and the crops at large. Despite the great potential of alluvial floodplains for agricultural activities coupled with the perennial flow of the Pra River, it appears the communities such as Beposo, Oda and Daboase located along it are underutilizing the floodplains. It is therefore against this background that this study sought to experiment with alluvial floodplains soil and its potential for agricultural development in Ghana focusing on the River Pra floodplain. The following research questions guided the study: What is the level of crop-growing potential of the alluvial floodplains of River Pra? How many heavy metals have been assimilated by the crops cultivated in the area?

2.0 MATERIALS AND METHODS

2.1. Study area

This study was carried out in the Pra River catchment which is located between latitudes 5º00'N and 7º15'N and longitudes 0º03'W and 2º80'W. It originates from Kwahu Plateau, near Mpraeso in the Eastern Region and flows southward over 230 kilometres through rich cocoa and farming and forest areas in the Akan lowlands and enters the Gulf of Guinea in Shama.

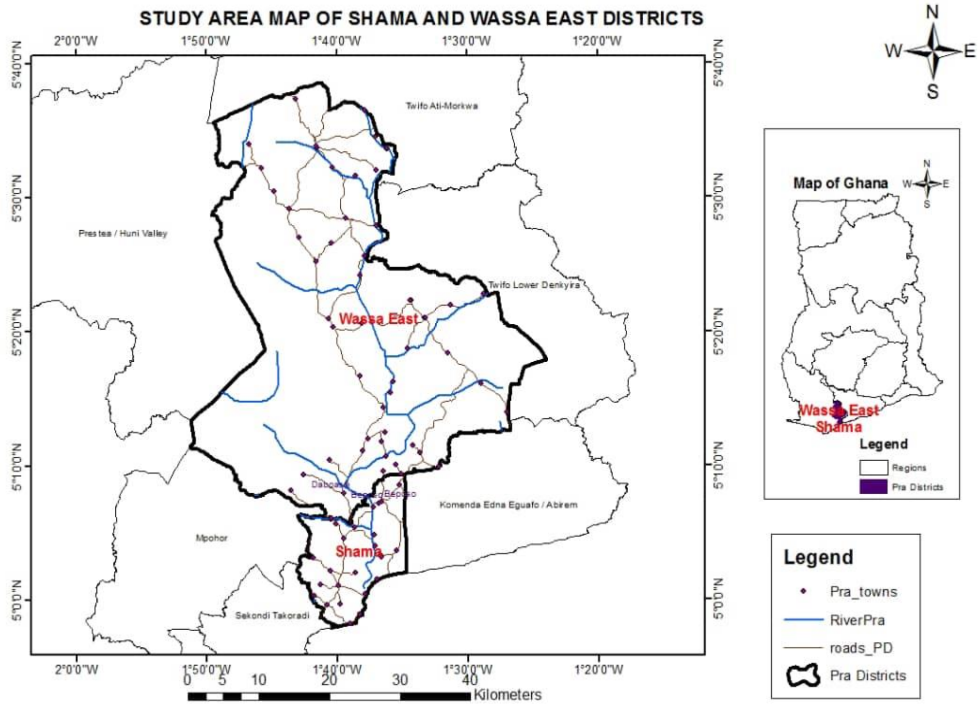

Figure 1: Study area map
Source: Author's construct from ArcGis 10.1 (2019)

The Pra is the largest of the four principal rivers that drain the area south of the Volta divide and enters the Gulf of Guinea east of Takoradi. Its main tributaries are the Ofin, Anum and

Birim rivers which drain from the Mampong-Kwahu Ranges. The drainage basin area is 23,188 km2 with a mean annual discharge of 214 m3s-1 (Akrasi and Ansa-Asare, 2008). The landscape is generally flat characterized by undulating topography with an average elevation of about 450 m above sea level.

2.2. Crop sampling

The crops used for the research were selected to suit the time frame of the study. Three varieties of crops were used for the study: Cereal (maize), vegetable (okra), and Legumes (cowpea). These crops were selected to be used for the study also because they are the crops mostly cultivated along the Pra River floodplain. Again, another major basis for these crop sampling was the maturity period of the crops. For the research, the crops must be cultivated and yield within a specified period. This was so since the results were used to analyze the data which were gathered in the process of the cultivation and maturity period.

2.3. Cultivation of crops

15 feet by 30 feet land was cleared for the cultivation of the crops. Stumps were removed after the clearing to make the land more bear. Lining and pegging were following to help cultivate the crops in a linear form (Figure 2). These activities were done for both Daboase and Beposo all along the floodplain of the Pra River. Planting of the crops (maize, cowpea, okra) followed. Planting was done on 22nd August 2019 at Daboase and 20th September 2019 at Beposo respectively.

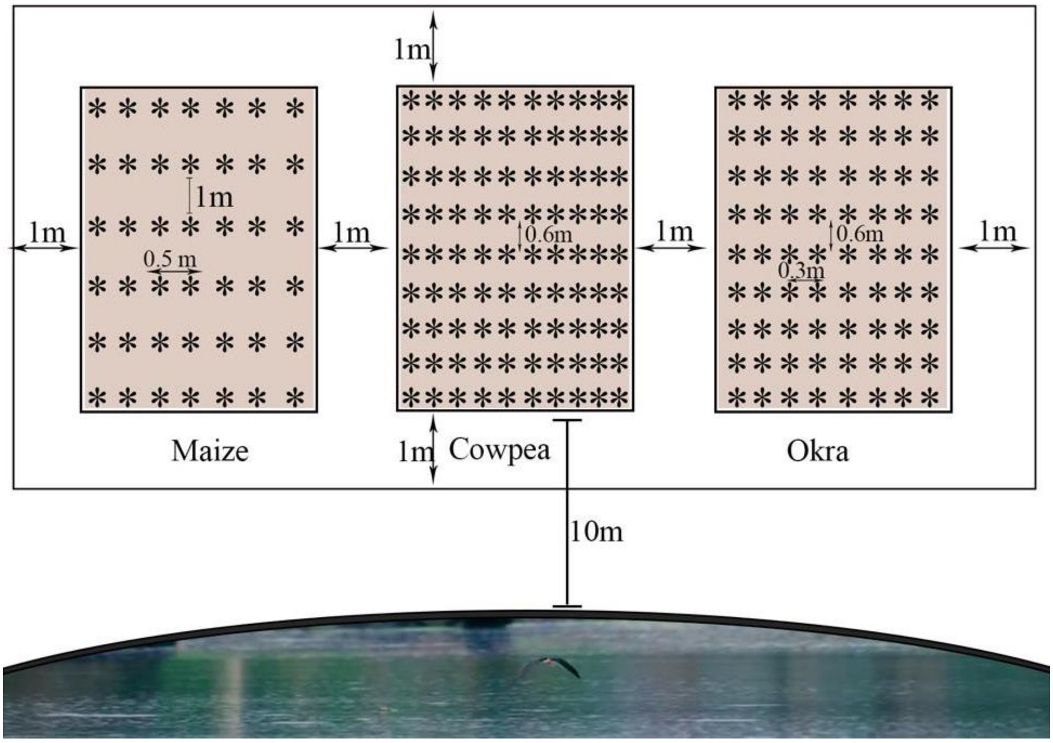

Figure 2: Experimental Model for crops cultivation
Source: Author's construct, 2019

2.4 Obtaining crop data

The maize germinated on the fifth day after the planting while the okra and cowpea germinated on the fourth day after planting. In other to obtain the quantitative data on the crops, measurements were taken on the crops at a different point in time. The measurements were done on the first two weeks after germination, the fourth week, the sixth week, the eighth week, the tenth week and finally on the twelfth week. These measurements were only taken at Beposo since the crops at Daboase did not do well after germination.

2.5. Determination of heavy metals in crops

The crop samples were air-dried, crushed and sieved through a 2 mm mesh. The sieved crops were stored in polythene bags for laboratory analyses.

Weigh 0.5g of sample and add15ml of concentrated nitric acid.

Boil to almost dryness and cool.

Add 1ml of hydrofluoric acid and boil.

Filter and top to 20ml with distilled water

Estimate the concentration of heavy metals with Atomic Absorption Spectrophotometer after calibrating with specific standards.

2.6. Statistical analysis

Data obtained were entered using Microsoft Excel 2016. The data was further organized and analyzed with the Statistical Package for Social Sciences (SPSS) version 25.0. Descriptive statistics and frequency tables and figures were designed based on the specific objectives. All statistical tests were tested at a 95% significance level and results were represented in Tables and Figures.

3.0 RESULTS

3.1: Morphological Trait of Maize

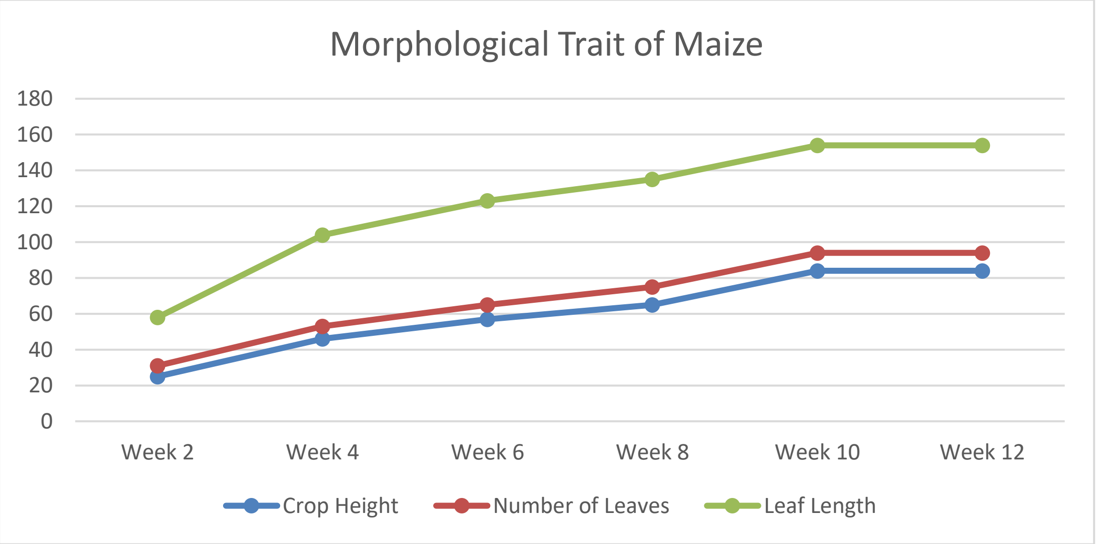

Figure 3: Maize

Source: Field data, 2019

Inline to achieve the objective of the crop-growing potential of the Pra River floodplain, similar measurements were also done on maize. Measurements were done on the crop height, the number of leaves and the leaf length, six consecutive times with an interval of two weeks. From Figure 3, the height of the sample of maize kept a progressive increment from the 2nd week to the 12th week with values from 28cm to 86cm. It was observed that the number of leaves on the crop kept increasing from the 2nd week to the 8th week until it remained stable to the 12th week. This can be attributed to the crop maintaining its number of leaves after the 8th week with 10 leaves. The leaf length also increased from the 2nd week to the 6th week and became stable till maturity in the 12th week.

This increment was seen at the 6th and 8th week also. On the contrary, the 10th and 12th weeks both had equal figures for crop height (90cm), the number of leaves (9) and the leaf length (62cm).

The reduction in the leaf length could be attributed to the older leaves falling off to make way for the new ones.

From Figure 4, the height of the cowpea plant was measured together with the number of leaves and leaf length over six (6) consecutive times with a space of two (2) weeks each. From the measurements above, there is a progressive increase in the plant height, leaf number and leaf length. For instance, the height recorded after two weeks of planting was 20cm. At this height, the total number of leaves of the sampled plant was 8 with an average leaf length of 6cm. After two weeks, the measurement of the same traits was done.

3.2: Morphological Trait of Cowpea

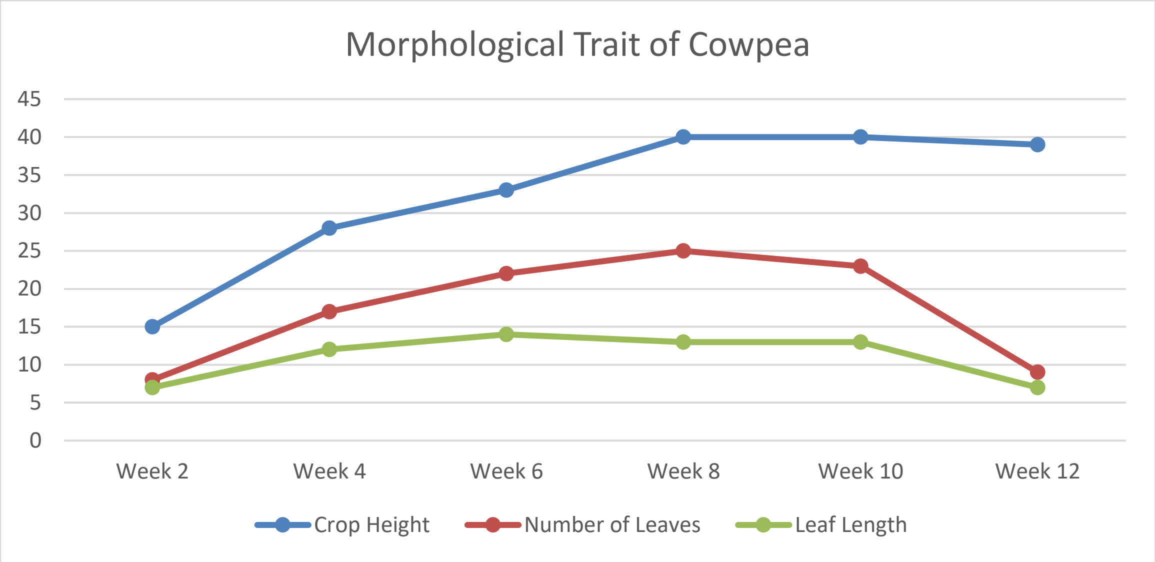

Figure 4: Cowpea

Source: Field data, 2019

It was observed that; the plant height has increased more than 50% whiles the number of leaves doubles. The leaf length also doubled over the two weeks from 6cm to 12cm.

This implies that; the floodplains of the Pra River provided the plant with the requisite nutritional environment for growth.

This may be attributed to the fact that individual plants may have their peculiar growth patterns though within the same land area. Thus, the number of leaves is likely to be independent of the crop height. This may be attributed to the leaf length of the cowpea sample which was 9cm, longer than both leaf lengths of cowpea samples 1 and 2. Several environmental factors may have accounted for this as they grow to maturity. These have been characteristics of most of the samples taken. It can be concluded that as the plant grows, it tends to increase in its leaves and in the process of maturing, sheds those leaves.

3.3: Morphological Trait of Maize

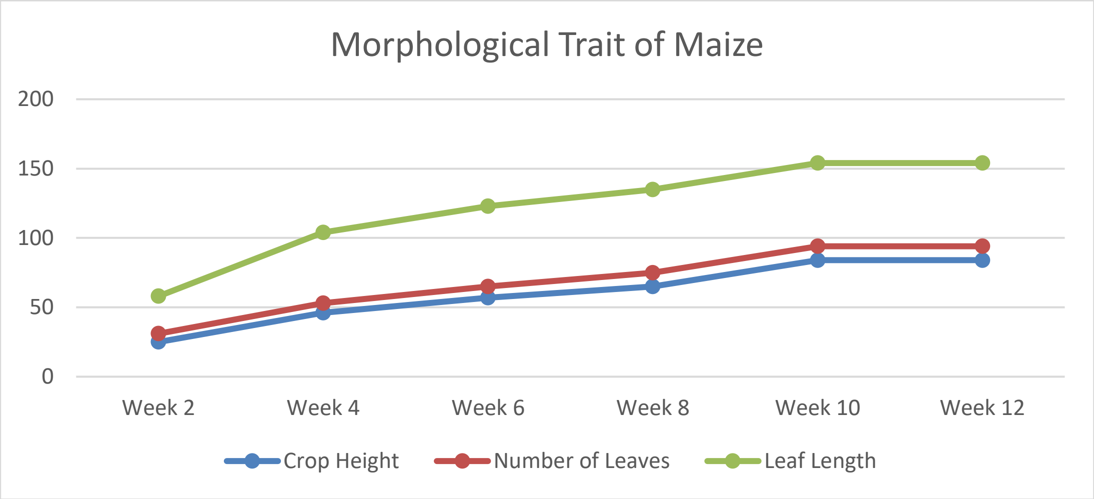

Figure 5: Maize

Source: Field data, 2019

Inline to achieve the objective of the crop-growing potential of the Pra River floodplain, similar measurements were also done on maize. Measurements were done on the crop height, the number of leaves and the leaf length, six consecutive times with an interval of two weeks. From Figure 5, the height of the sample of maize kept a progressive increment from the 2nd week to the 12th week with values from 28cm to 86cm. It was observed that the number of leaves on the crop kept increasing from the 2nd week to the 8th week until it remained stable to the 12th week. This can be attributed to the crop maintaining its number of leaves after the 8th week with 10 leaves. The leaf length also increased from the 2nd week to the 6th week and became stable till maturity in the 12th week.

This increment was seen at the 6th and 8th week also. On the contrary, the 10th and 12th weeks both had equal figures for crop height (90cm), the number of leaves (9) and the leaf length (62cm).

The reduction in the leaf length could be attributed to the older leaves falling off to make way for the new ones.

3.4: Morphological Trait of Okra

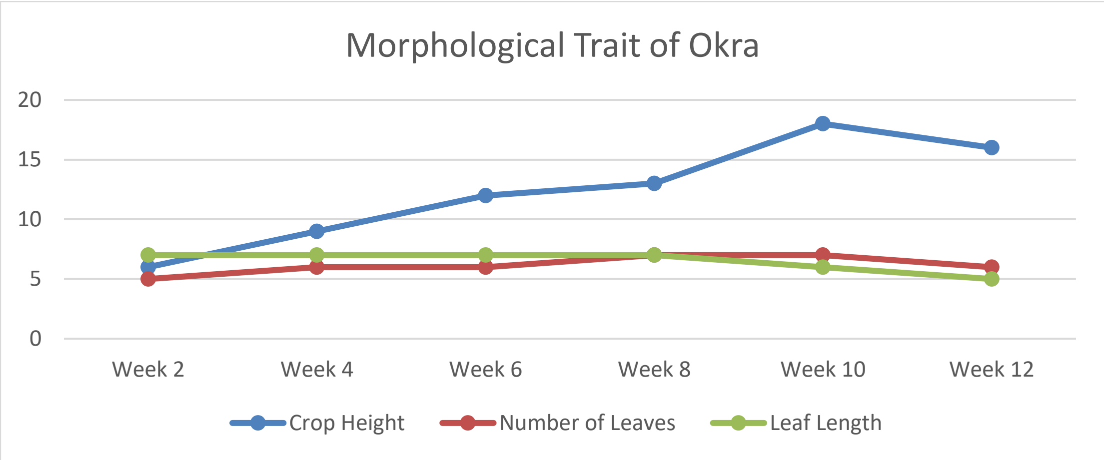

Figure 5: Okra

Source: Field data, 2019

A third crop, okra, was among the crops cultivated along the Pra River floodplain for the research. Measurements were equally taken on sampled crops to help discuss the morphological traits of okra. In the 2nd week, okra sample 1 had a crop height of 6cm with 5 leaves and a leaf length of 8cm. The crop height increased to 8cm with 6 leaves and a leaf length of 8cm during the 4th week. The 6th week had a crop height of 14cm with 7 leaves and 6cm for leaf length. The 8th and 10th weeks recorded an equal crop height of 17cm with the 8th week recording 8 leaves and a leaf length of 8cm while the 10th week recorded 6 leaves with leaf length at 5cm. During the 12th week, the crop height increased to 22cm with 6 leaves and a leaf length of 6cm.

Regarding the other sampled crops, it can be observed that okra developed very weak morphological traits during its cultivation in the floodplain. The results from the measurements could be attributed to the low nutrient composition available to these crops.

3.4. Heavy Metal Assimilation by crops

Table 1: Assimilation of Heavy Metals in the Crops of Bepose measured at 14m from the River

Label	Assimilation of Heavy Metals by crops			
	Pb mg/kg	**Cd mg/kg**	**As mg/kg**	**Hg ppb**
M 14m	0.07	0.003	4.36	**0.3**
C2 14m	0.04	0.004	3.79	**0.3**
O1 14m	0.045	0.007	4.96	**0.21**

C: Cowpea, O: Okra, M: Maize, Pb: Lead, Cd: Cadmium, As Arsenic, Hg: Mercury

Source: Field data, 2020

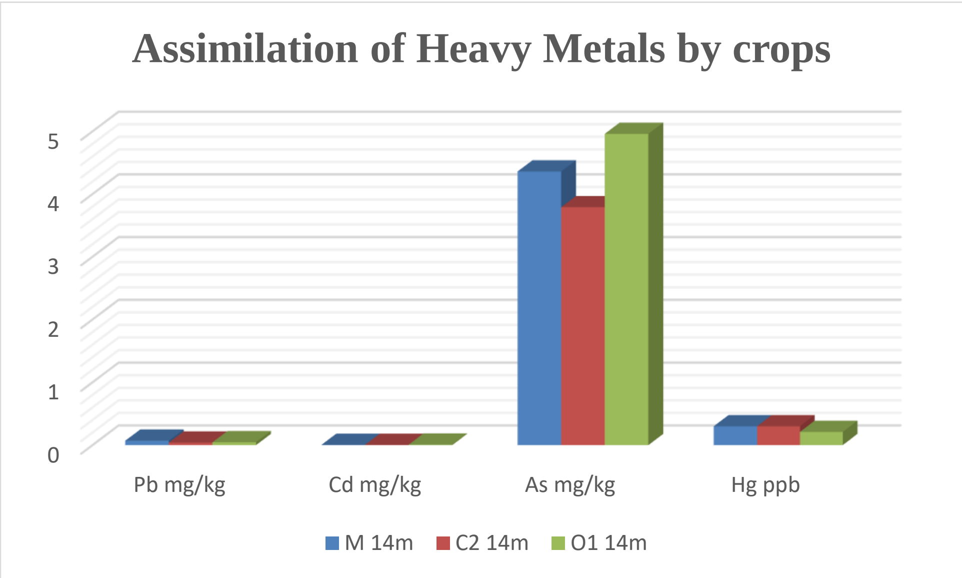

Figure 6: Assimilation of Heavy Metals in the Crops of Bepose measured at 14m from the River
Source: Field data, 2020

Arsenic, lead, cadmium and mercury were tested in three different crops cultivated along the Pra River floodplain. From the results, it was observed that the crops had assimilated a certain amount of these heavy metals in their edible parts with arsenic having the highest in terms of value. These metals were earlier tested for in the soil and were noted to be concentrated in the soil. It was found out that, the crops had assimilated the metals from the concentration available to them in the soil. These four heavy metals (As, Pb, Cd, and Hg) have also been regarded as the most toxic metals by the Agency for Toxic Substances and Disease Registry (ATSDR 2003) based on their toxicity, frequency of occurrence, and human exposure potential.

3.5: Correlational analysis of the relation between leaf length and crop height for maize.

From table 2, it can be observed that leaf length for maize was found to be positively correlated (Spearman correlation= 0.955) with crop height for maize. This relationship however was found to be statistically significant (p-value= 0.003).

Table 2: Correlational analysis of the relation between leaf length and crop height for maize.

Spearman's rho	**Crop Height(maize)**		
	Rs	N	p-value
Leaf Length (Maize)	0.955	6	0.003

**. Correlation is significant at the 0.01 level (2-tailed).

4. DISCUSSION

Morphological traits analysis of plants including plant height, leaf number, and leaf height enables monitoring changes in a plant in response to factors such as light availability, soil compaction, and organic matter removal (Abrams & Kubiske, 1990). In this study, the morphological traits of cowpea, maize and okra (plant height, leaf height and leaf number) were measured to help understand the environmental conditions of the floodplains of River Pra along the Daboase-Beposo stretch. These morphological traits were manually measured at different stages during the life cycle of the plant. A two-week interval was used for taking those measurements. The results of measurement helped to monitor the growth of the crops over the period. At certain stages, it was observed that the general structure of the crops had changed. Leaves on the crops changed from green to yellowish which can be attributed to low soil organic matter and nitrogen as well as phosphorous. These nutrients facilitate crops development. Hence, a low rate or lack of them causes sluggish growth of crops and further affects the level of crop yield potential.

The result shows some heavy metals assimilation of the crops. However, a small amount of these heavy metals in the edible parts of crops can be detrimental to human health. Singh et al. (2010 a) reported toxic effects of Zn and Cd due to consumption of vegetables cultivated in heavy metal polluted soil in India.

Similarly, Bigdeli and Seilsepour (2008) forecast an expected hazard in Iran due to the daily intake of Cd, Zn, and Pb from heavy metal contaminated sites. Reduced crop productivity is also a consequence of soil heavy metal contamination. Excessive heavy metal accumulation in plant tissue impairs either directly or indirectly several biochemical, physiological, and morphological functions in plants and turns interferes with crop productivity. Heavy metals reduce crop productivity by inducing deleterious effects to various physiological processes in plants including seed germination, accumulation and remobilization of seed reserves during germination, plant growth, and photosynthesis.

Leaf structure and physiology are changed along with the reduction in photosynthesis and respiration. As a result of these changes, metabolism is affected and energy production is reduced. Therefore, various developmental processes including flowering, embryogenesis and seed formation are affected due to changes in the functioning of the root and leaf. The greatest risk of food chain contamination is in leafy vegetables like lettuce or spinach. Kumar et al, (2019) commented that heavy metals have led to unanticipated toxins in crops which have also affected food security in several parts of the world. This is because heavy metals affect the microbial component of soil.

Among various heavy metals, cadmium (Cd) is considered very toxic for plants (Waalkes 2000), inhibiting photosynthesis (Qian et al. 2009) and reducing root and shoot growth. Soils that are acidified enhance the cadmium uptake by plants. Cadmium, a nonessential element for plant growth, is taken up by the roots and translocated to the vegetative parts of the plant, which degrades the quality as well as the yield of crops (Hassan et al.2005). A study in China showed that sewage on maize crops intensify heavy metals content yet do not affect maize growth and the dryness of the crop tissues (Bai, et al., 2016). Also, heavy metals in wastewater irrigation on maize crops end up in the crops assimilating more of Cr, Pb, Ni, and Zn (Lu et al., 2015). They also confirmed that the intake of heavy metals in maize crop is less than that of the soil on which it is planted after the application of fertilizers.

Plate 1: Experimental Model

Source: Field data, 2019

5. CONCLUSIONS

The growing pace and potential level of the crops cultivated along the Pra River floodplain exhibited fewer amount nutrients in the alluvial soil with the morphological trait of the crops varying from weeks to weeks. Some of their leaves turned yellowish in the course of their growth process exhibiting a major deficiency in macronutrients in the soil especially phosphorus which was observed from the result to be in less proportion as required by the crops cultivated along the floodplain. The crops also exhibited some level of heavy metal assimilation.

6. RECOMMENDATIONS

1. For the identification of suitable remedial options, relevant information of the sources, chemistry, and associated dangers of harmful pollutants in contaminated soils is necessary. For the identification of suitable remedial options, relevant information of the sources, chemistry, and associated dangers of harmful pollutants in contaminated soils is necessary. It is recommended that, to reduce the acidity level in the alluvial soil, the soil should be limed continuously. Crops that do well in acidic soils such as potato, should be cultivated within the Pra River floodplain.

2. Also, to increase soil nutrient for abundant productivity, the Ministry of Food and Agriculture (MOFA) should support farmers with organic fertilizers, manure as well as nitrogen-fixing seeds to help them improve the richness level of the soil to enhance productivity food security and sustainability.

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REFERENCES

Abrams, M. D. & Kubiske, M. E. (1990). Leaf structural characteristics of 31 hardwood and conifer tree species in Central Wisconsin: influence of light regime and shade-tolerance rank. *For. Ecol. Manage.,* 31: 245-253.

Ailenokhuoria, B., & Omolekan, T. (2019, November 4). Heavy Metal, Proximate and Antioxidant Composition of Five Cultivars of Cowpea (Vigna unguiculata) in Ibadan, Oyo State Nigeria. *Journal of Food Science and Nutrition Research,* 327-332.

Akrasi, S. A. and Ansa-Asare, O. D. (2008). Assessing Sediment and Nutrient Transport in the Pra Basin of Ghana. *West African Journal of Applied Ecology,* Vol. 13, pp.111.

Anim-Gyampo, M., Kumi, M., & Zango, M. S. (2013). Heavy metals concentrations in some selected fish species in Tono Irrigation Reservoir in Navrongo, Ghana. *Journal of Environment and Earth Science*, *3*(1), 109-119.

ATSDR (2003) Agency for toxic substances and disease registry. http://www.atsdr.cdc.gov/

Bai, Y.-C., Zuo, W.-G., Zhao, H.-T., Mei, L.-J., Gu, C.-H., Guan, Y.-X., . . . Feng, K. (2016, December 17). Distribution of heavy metals in maize and mudflat saline soil amended by sewage sludge. *Journal of Soils and Sediments*.

Banchirigah, S. M. (2008). Challenges with eradicating illegal mining in Ghana: A perspective from the grassroots. *Resources Policy*, *33*(1), 29-38.

Beilfuss, R. (2002). Indicators of hydrological change in the Lower Zambezi River.

Bigdeli M, Seilsepour M (2008) Investigation of metals accumulation in some vegetables irrigated with wastewater in Shahre Rey-Iran and toxicological implications. *Am-Euras J Agric Environ Sci* 4(1):86–92

Chibuike, G. U., & Obiora, S. C. (2014). *Heavy Metal Polluted Soils: Effect on Plants and Bioremediation Methods*. *2014*.

Dorleku, M. K., Nukpezah, D., & Carboo, D. (2018). Effects of small-scale gold mining on heavy metal levels in groundwater in the Lower Pra Basin of Ghana. *Applied Water Science*, *8*(5), 1-11.

Duncan, A. E. (2020). The Dangerous Couple: Illegal Mining and Water Pollution—A Case Study in Fena River in the Ashanti Region of Ghana. *Journal of Chemistry*, *2020*.

FAO/WHO (2011). *Expert consultation on the risks and benefits of fish consumption*. Geneva, Switzerland: WHO Press.

Hassan M. J., Shao, G., Zhang, G. (2005). Influence of cadmium toxicity on antioxidant enzymes activity in rice cultivars with different grain Cd accumulation. *J Plant Nutr* 28:1259–1270

Jamal, Q., Khan, K., Munir, S., & Anees, M. (2013). *Heavy Metals Accumulation and Their Toxic Effects: Review Heavy Metals Accumulation and Their Toxic Effects: Review*. (January).

Kumar, P., Soo, S., Zhang, M., Fai, Y., & Kim, K. (2019). Heavy metals in food crops: Health risks, fate, mechanisms, and management. *Environment International*, *125*(November 2018), 365–385. https://doi.org/10.1016/j.envint.2019.01.067

Lu, Y., Yao, H., Shan, D., Jiang, Y., Zhang, S., & Yang, J. (2015). *Heavy Metal Residues in Soil and Accumulation in Maize at Long-Term Wastewater Irrigation Area in Tongliao China*. *2015*.

Ma, J., Chen, Y., Vasileious, A., Wang, K., Huang, Y., & Tian, H. (2020, January 20). Assessment of heavy metal(loid)s contamination risk and grain nutritional quality in organic waste-amended soil. *Journal of Hazardous Materials*. Retrieved 2020, from https://www.sciencedirect.com/science/article/abs/pii/S0304389420310840

Mensah, A. K., Mahiri, I. O., Owusu, O., Mireku, O. D., Wireko, I., & Kissi, E. A. (2015). Environmental impacts of mining: a study of mining communities in Ghana. *Applied Ecology and Environmental Sciences*, *3*(3), 81-94.

Nyarko, B. J. (2001). Determination of arsenic in some water bodies, untreated ore and tailing samples at Konongo in the Ashanti region of Ghana and its surrounding towns and villages by instrumental neutron activation analysis. *Journal of Radioanalytical and Nuclear Chemistry*, *249*(3), 581-585.

Ohanmu, O. E., & Ikhajiagbe, B. (2018, November 29). Effect of Cadmium Pollution on Nitrogen Assimilation and Biomass Accumulation of Vigna unguiculata L... Asian. *Journal of Applied Sciences*, 11: 183-191. doi:10.3923/ajaps.2018.183.191

Qian, H., Li, J., Sun, L., Chen, W., Sheng, G. D, Liu, W., & Fu, Z. (2009) Combined effect of copper and cadmium on Chlorella Vulgaris growth and photosynthesis-related gene transcription. *Aquat Toxicol* 94:56–61

Singh, S., Nag, S. K., Kundu, S.S., Maity, S.B. (2010). Relative intake, eating pattern, nutrient digestibility, nitrogen metabolism, fermentation pattern and growth performance of lamb fed organically and inorganically produced cowpea hay-barley grain diets. Trop. Grass., 44: 55-61

U.S. EPA (Environmental Protection Agency). (2007). *Framework for Metals Risk Assessment*. Office of the Science Advisor Risk Assessment Forum, Washington, DC; EPA 20460. www.epa.gov/osa

Waalkes, M. P. (2000). Cadmium carcinogenesis in review. *J Inorg Biochem* 79:241–244

BIOGRAPHICAL NOTES

Prof. Isaac Boateng

Isaac is a keen individual with interdisciplinary knowledge. He has over 20 years' worth of professional experience in teaching and learning in higher education. He has been a fellow of the UK Higher Education Academy since 2009. Isaac's research and consultancy interest are in the area of Coastal Engineering, Climate Change adaptation, coastal management and applied coastal and fluvial geomorphology. Isaac has been involved in FIG activities since 2006. He has authored several FIG conference papers, including Working group and taskforce Publication on surveyors' role in coastal management and climate change adaptation (see FIG publication 36, 55 and 65). He was a Senior Lecturer at the University of Portsmouth in the UK for over 11 years. Currently, he is the Dean of Faculty of Business Education at the Akenten Appiah-Menka University of Skill Training and Entrepreneurial Development (AAMUSTED) in Ghana.

Ms Ellen Kwarteng

Ellen is a young geographer with keen interest in crop and plant science as well as fluvial geomorphology. She has currently completed Master of Philosophy in Geography Education from the University of Education, Winneba. She has done researches on river management and crop cultivation.

Dr. Kofi Adu-Boahen

Kofi is a young fluvial geomorphologist and possess diverse knowledge in water resources monitoring and management. He is an academic and researcher. Currently, he is the Head of Quality Assurance and Assessment at the Institute of Teacher Education and Continuing

Professional Development (ITECPD, UEW, Ghana). His research interest spans around coastal geomorphology, environmental management, riverine and lagoon water quality analysis. He currently working on ecosystem restoration and management. Now working with 15 colleges of education in Ghana affiliated to the University of Education, Winneba.

CONTACTS

Prof Isaac Boateng
Apenten Appiah Menka University of Enterpreneural and Skills Developement
Kumasi, Ghana
Tel. + 2330203496339
Email:issac.boateng@uew.edu.gh
Web site: aamusted.edu.gh

Ms Ellen Kwarteng
University of Education,Winneba
Depertment of Geography, Box 25
Winneba, Ghana
Tel. +002330543300179; Email: kwartengellen@gmail.com
Web site: www.uew.edu.gh

Dr Kofi Adu-Boahen
University of Education,Winneba
Depertment of Geography, Box 25 Box 25
Winneba, Ghana
Tel. +002330243778237
Email: kadu-boahen@uew.edu.gh
Web site: www.uew.edu.gh