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Characterization of Soil Conditions for Wild Edible Plants' Habitats in Semi-Arid Areas of Uganda

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***Abstract* – Wild edible plants are known to supplement farm crops in rural African households, especially during famine periods. In Uganda, conservation of such plants is at stake. Their habitats are continuously being degraded or converted to other land uses. Assessment of soils on agriculture land is common, but limited for wild edible plants' habitats. A study was done to characterize and compare soil physical and chemical properties of wild edible plants' habitats and farmers' gardens for the purpose of assessing the potential for cultivation of the plants on the gardens. Soils 0-20 cm and 30-50 cm deep were randomly sampled from the rhizosphere of the selected plants and from gardens of farmers. Soil samples were analyzed using published standard procedures. Fisher's test was used to compare the soil conditions of the wild edible plants' habitats for homogeneity, Pearson's correlation coefficient to find association between the plants occurrence and their habitats soil conditions, and ANOVA to establish differences between the soil properties of the wild edible plants' habitats and farmers' gardens. The soil physical and chemical conditions of the different habitats where the wild edible plants naturally grow were similar ($p>0.05$), highly associated with the plants' occurrence($r>0.5$) and significantly more fertile ($p<0.05$) than farmers' gardens. On-farm establishment of the wild edible plants could require soil amendment.**

***Keywords* – Conservation, Food Plants, On-Farm, Soil Properties, Spontaneously Growing.**

I. INTRODUCTION

Wild edible plants are those food plants, found growing naturally on field or on communal lands without being planted [1]**.** They may include food plants that are only found in the wild or some leafy vegetables that grow spontaneously in banana plantations and abandoned farmlands thus they are referred to as secondary crops. They may also be indigenous or exotic and in some parts of the world where they originate they may be already in cultivation. For instance *Amarathus dubius*, *A. hydridus* and *A. lividus* that originate from Central America are common vegetables which are often cultivated in other parts of the world. However, in Uganda the species have apparently escaped into the wild [2] **.**

Although Uganda is well endowed with a diversity of indigenous wild edible plants; about 200 species uncultivated with potential commercial, medicinal and nutritional values, domestication of wild edible plants has been limited due to inadequate knowledge about their agronomy yet their conservation is at stake[3],[4]. Also lacking is the characteristics of their ecological requirements especially the soil conditions for their on-farm management to improve their conservation for household food security and income.

Growth and productivity of wild plants just as it is for crops are highly related to soil conditions including the temperature, texture, drainage, bulk density, depth, organic matter, pH, electro conductivity, cation exchange capacity and nutrients [5]-[7]. For example wild blue berry prefers soils with light acidity of pH 5.5, less water but not poorly drained thus is well adapted to drought while the wild yams require loose loam soils with good drainage and high fertility [8],[9]. Basil (*Ocimum gratissimum*) *can* grow in most types of soils including even those that are nutritionally poor, thus having a wide adaptability. Whereas, *Ocimum gratissimum* prefers sandy-silt loam, loamy and clay soils which are slightly acidic pH 6.4, well drained but with good water holding capacity, high in humus and rich in nutrients [10]. It also prefers neutral and alkaline soils, although, it can tolerate very acidic to very alkaline soils in the range of pH 4.3-8.4 [11]. Cape goose berry (*Physalis peruviana*) does well in relatively poor soils as fertile soils only favor its vegetative growth over fruit production [12]. However, it is possible to amend all soil conditions except texture, either mechanically or by addition of inputs to suit the growth and productivity requirements of a particular plant [13]-[15].

Currently, in Uganda, wild edible plants are being lost due to land degradation through overgrazing, deforestation and reclamation. As the population grows and land pressures intensify, it is increasingly important that, the wild edible plants are protected. This study therefore, determined and compared the soil physical and chemical properties of the wild edible plants' habitats and farmers' gardens to aid understanding for their on-farm conservation for wider and sustainable use.

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II. Materials and Methods

2.1 Study area description

The study was conducted in Nakasongola district which is located in central Uganda and lies between latitudes: 0° 57' North and 1° 41' North and longitudes**:** 31° 57' East and 32° 48' East on Bombo-Gulu Highway, 114 Km north of Kampala.

The annual mean daily maximum temperature is 30°C. Rainfall ranges between 500 to 1000 mm with two seasons annually. The main rain season occurs from March-April to June-July while the second rain season follows from August to October-November [16]. A long dry season occurs from December to February while a short spell comes around July-August. The soils of Nakasongola district are relatively homogeneous but strongly weathered with high sesquioxide content and therefore referred to as *haplic ferralsols* and thus poor [17].

2.2 Survey and soil sampling

Two sub-counties and a parish within each, known for consumption of wild edible plants were selected for the study through consultation of the local district leaders. The sub-counties selected are the areas in Nakasongola still surrounded by natural woodland unlike the others where the natural vegetation is almost lacking due to charcoal burning, overgrazing and wetland reclamation. Through individual household interviews, all households in the selected parishes were asked to name and rank in order of importance the wild edible plants they traditionally consume by questioning only one respondent aged 10 years and above per household. Individual household interviews were conducted to eliminate peer influence and improve data quality [18]. Children aged 10 years and above were included, for children have been reported to form the majority of wild edible plants collectors [19].

Three plants among the ten most highly ranked wild edible plants were selected for the study of soil properties in their habitats. The selected plants were Cape goose berry (*Physalis peruviana), Basil (Ocimum gratissimum)* and Aerial yam (*Dioscorea bulbifera).* Soils 0-20 cm and 30-50 cm deep were collected by random sampling from the wild edible plants root zones within 10 m ×10 m quadrants laid on the plants sites. From each quadrant, soil samples were taken from the plants root zones in triplicate to make composites. For every selected wild edible plant type, in each sub-county soil samples were picked from four sites. Additionally, within each laid quadrant, the plant species populations were counted to assess association between their occurrence and the habitat soil conditions [20]. Soils 0-20 cm and 30-50 cm deep were sampled in triplicate to make composites from the gardens of each of the four farmers selected from each of the two sub-counties. Soils samples were taken from 0-20 cm and 30-50 cm depths because some of the wild edible plants are herbs and shrubs whose roots mainly spread into the surface soils while those in form of trees may have roots penetrating the soil as deep as 50 cm.

2.3 Determination of soil physical and chemical properties

The soil samples were analyzed for texture, bulk density (BD), field water holding capacity (WHC), pH, electro conductivity (Ec), exchangeable cations (Ca, Mg, K, Na), organic matter (O.M) content, total nitrogen (T.N) and trace elements (copper; Cu, zinc; Zn, iron; Fe and manganese; Mn) according to methods in [21] and for available phosphorus (Av. P), according to Bray and Kurtz P-1 method [22].

2.4 Data analysis

Fisher's test of significance was used to test, first, the wild edible plants' habitats physical and chemical soil conditions for homogeneity. Analysis of variance (ANOVA) was then used to establish variation between the physical and chemical soil properties of wild edible plants' habitats and farmers' gardens and separate their mean values by method of probability of difference between means, Eigen values and variability% to analyze the principal physical and chemical soil properties in the wild edible plants' habitats and their association with the plants occurrence respectively. Fisher's test was of PAST Window 2000 software while ANOVA, Eigen values and variability% were of Package for Social Scientists (SSPS) software 2002.

III. Results

3.1 Variation among habitats of wild edible plants soil conditions

There were no significant differences ($p>0.05$) in the physical and chemical characteristics of the soils in the wild edible plants' habitats (Table I). However, Mg (602 mg kg^{-1}), K (165 mg kg^{-1}) and Ca (365 mg kg^{-1}) were higher in Croplands

3.2 Comparison between wild edible plants' habitats and farmers' garden physical and chemical soil properties

The soil pH and nutrient levels were generally higher for both 0-20 cm and 30-50 cm depth in the wild edible plants' habitats than in farmers' gardens (Table II). However, physical and chemical soil characteristics of wild edible plants' habitats and farmers' gardens were significant different ($p<0.05$) in terms of pH, K, Zn and bulk density (BD). Soils of farmers' gardens were very acidic (pH 4.9 top soil; 4.5 sub soil) , lower in K (81.5 mg kg-1 top soil; 47.14 mg kg-1 sub soil) and Zn (1.50 mg kg-1 top soil; 0.90 mg kg-1 subsoil) and more compacted (BD 2.11g cm-3 top soil; 1.61g cm-3 sub soil). In the wild edible plants' habitats pH were slightly acidic 5.4 for top soil; 4.8 sub soils, K was 122.54 mg kg-1 for top soil; 99.18 mg kg-1 sub soil, Zn was 1.79 mg kg-1 for top soil; 1.21 mg kg-1 for sub soil and bulk density 1.50g cm-3 for top soil; 1.56g cm-1 sub soil.

There were no significant variations ($p>0.05$) in the physical and chemical soil conditions by depth for both farmers' gardens and wild edible plants' habitats. Furthermore, the soil nutrient of both farmers' gardens and wild edible plants' habitats were above critical levels. The soils were both sandy clay loam in texture although their field water holding capacities were below the critical level of 50% (weight of water per weight of soil). The electro

conductivity levels for both soils were normal as there were below the critical level of 0.00045 Sm^{-1} that negatively affect normal plant growth [5].

Table I. p values for Fisher's test for variation among wild edible plants' habitat soil conditions

	Crop land	Fallow land	Wood land
Crop land	1	0.775	**0.322**
Fallow land	**0.775**	1	0.143
Woodland	0.322	**0.143**	1

Table II: Physical and chemical soil properties of wild edible plants habitats and farmers' gardens by depth.

Soil property	Farmers' gardens		Wild edible plants natural habitats	
	0-20 cm	30-50cm	0-20 cm	30-50 cm
pH	4.9^{a}	4.5^{a}	5.4^{b}	4.8^{a}
Ec.Sm^{-1}	0.003^{a}	0.002^{b}	0.003^{a}	0.003^{a}
OM %	1.9^{a}	1.9^{a}	2.1^{a}	1.6^{a}
TN %	0.2^{a}	0.2^{a}	0.2^{a}	0.1^{a}
Avail. P mg kg^{-1}	7.53^{a}	7.60^{a}	7.93^{a}	8.85^{a}
Ca mg kg^{-1}	327.60^{ab}	201.60^{b}	370.44^{a}	241.91^{b}
Mg mg kg^{-1}	201.03^{a}	185.46^{a}	256.41^{a}	319.60^{a}
K mg kg^{-1}	81.51^{ab}	47.14^{b}	122.54^{a}	99.18^{ab}
Na mg kg^{-1}	143.39^{a}	98.78^{a}	165.31^{a}	159.08^{a}
Fe mg kg^{-1}	107.64^{ab}	70.16^{b}	128.38^{a}	103.31^{ab}
Cu mg kg^{-1}	2.05^{a}	1.66^{a}	1.75^{a}	1.91^{a}
Zn mg kg^{-1}	1.50^{a}	0.90^{b}	1.79^{a}	1.21^{b}
Mn mg kg^{-1}	97.94^{a}	69.90^{a}	92.92^{a}	74.61^{a}
CEC cmol kg^{-1}	11.49^{b}	23.50^{a}	18.28^{ab}	22.02^{a}
BD g cm^{-1}	2.11^{a}	1.61^{b}	1.50^{b}	1.56^{b}
WHC %	23.94^{a}	20.66^{a}	26.03^{a}	24.13^{a}
Clay %	24.00^{a}	31.75^{a}	26.04^{a}	28.80^{a}
Silt %	8.75^{b}	6.50^{b}	11.80^{a}	10.70^{ab}
Sand %	67.25^{a}	63.00^{a}	62.60^{a}	60.10^{a}
Texture	SCL	SL	SCL	SCL

All values in a row for each soil parameter followed by same letter are not significantly different.

3.3 Association between wild edible plants occurrence and their habitat soil conditions

Results indicated strong interaction between the soil physical and chemical factors and the occurrence of the wild edible plant species. Soil pH, Ec, OM, TN, Ca, K, Cu, Mn, Av.P, Fe, CEC, Na, BD, Mg were found to strongly (Eigen values>1 and Pearson correlation (r)>$^{\pm}$0.5) affect the natural occurrence of wild edible plant species although, pH, Ec., OM, TN, Ca, K, Cu, Mn were the major contributing soil factors (Eigen value = 4.667 or Variability = 29.2%). Thus for on-farm soil amendment for domestication of wild edible plants in Nakasongola, changing any two of those major soil factors for example pH and OM levels lead to the adjustment of the rest of the other soil physical and chemical conditions. Adjusting garden pH by liming, in addition to providing nutrient elements such Ca and Mg promotes availability of the other nutrients through improved microbial decomposition of organic matter and reduced fixation of phosphorus by Fe^{2+} and Al^{3+} ions. Application of organic matter such farmyard manure leads to reduction of garden soil compaction and improvement of CEC hence nutrient levels.

IV. Discussion

The higher levels of Mg, K and Ca in Cropland habitat of wild edible plants as compared to the woodland and fallow land could be attributed to the previous cultivation of or the then on-going growing potato and potato-cassava whose residues easily decompose to release basic cations. Sweet potatoes and cassava are crops known for heavy removal soil K, Mg , Ca and Zn nutrients , however if most of these crops residues are left on the soil after harvest the tubers, these nutrients are recycled through decomposition hence leading to maintenance of their high levels [23].

The low pH, K and Zn levels in farmers' gardens could be due to agricultural crop removal and cultivation. According to [24] crops such as maize, sweet potato and cassava have high demand for bases for their growth but the requirement for K is highest than for Ca and Mg. If the crop residues are not retained on the gardens as is usually the practice to harvest them for fuel and feed for animals or heaped along edges of gardens to clear off the field for the planting of the next crop, then the basic cations can be lost leading to their low levels in the soils. Cultivation on the other hand leads to improved aeration of soils which accelerate cation loss through leaching and organic acid formation from organic matter decomposition. Consequently, the low levels of K and Zn coupled with organic acids from organic matter decomposition may lead to very acidic conditions in farmers' gardens. Continuous cultivation may also lead to soil compaction as found in farmers' gardens as it leads to reduction of soil organic which would promote soil aggregation and aggregate pulverization thus causing close packing of soil particles.

The existence of soil nutrients in sufficient quantities in both wild edible plants' habitats and farmers' gardens was due to the sandy clay loam soil texture, thus the clay and humus particles in the soils were able to adsorb nutrients and keep the high levels [25]. The field water holding capacities of the soils were low possibly due water loss from the soil through evaporation caused by daily high temperature and extended dry weather. According to [26], in subtropical and tropical regions having prolonged dry season, soils lose water from greater depths through the crackings during drying as water vapor diffuses very fast from the surface of even deep cracks into the atmosphere. Additional the field water holding capacity of the soils are very low due to high water drainage as the soil texture of both wild edible plants' habitats and farmers' gardens were sandy clay loam.

The strong association between the occurrence of wild edible plant species and soil conditions in their habitats according to [8], is an indication that the diversity of wild plants that naturally occur in an area is determined by the soil conditions.

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Margaret Kyakuwaire is a Ugandan female born in Mulanda Sub-County Tororo Distric,Uganda on the 9th August 1968. I hold a degree of masters in Soil Science obtained in the year 2013 from Makerere University, P.O. Box 7062 Kampala, Uganda. I also hold a Bachelors degree in Science Technology Biological Sciences obtained iin 2006 from Kyambogo University of P.O. Box 1 Kyambogo, Kampala – Uganda. Prioir to the fore mentioned qualifications I had completed a Higher Diploma and an Ordinary Dilpoma in Science Technology Biology of Uganda Polytechnic Kyambogo P.O. Box Kampala Uganda in 2002 and 1990 respectively.
Currently I am working as a Chief Laboratory Technician for Kyambogo University where I had served as a Senior Laboratory Technician from 2009 to 2013 and as a Laboratory Technician from 2003 to 2009. In the year 2010 I also worked as a part- time Lecturer of General Microbiology in the same university. Kyambogo University came into after the merger of three former institutions; Institute of Teachers' Kyambogo (ITEK), Uganda Polytechnic Kyambogo (UPK) and Uganda National Institute of Special Education (UNISE). Before the university formation, I had worked as a Laboratory technician for ITEK from 1991 to 2003. For each of the award for the bachelors degree and higher diploma, I did research, but the findings were never published. However, currently I am preparing more three papers form my research for degree of masters for publication.

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