ECOLOGICAL IMPACTS AND UTILIZATION OF *Urtica dioica* L. IN NYERI COUNTY, KENYA

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University or any other award.

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DEDICATION

This thesis is devoted to the Almighty God, my dear parents led by the family patriarch grandfather Joseph Ng'ang'a for their encouragement and spiritual support throughout the study.

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
DF	Degrees of Freedom
IBMSPSS	International Business Machine Statistical Package for Social Sciences
KPHC	Kenya Population and Housing Census
NAAIAP	National Accelerated Agricultural Inputs Access Programme
UV	Ultra Violet
IAPS	Invasive Alien Plant Species
SDG	Sustainable Development Goals
WEP	Wild edible plant
IPM	Integrated Pest Management
LUTS	Lower Urinary Tract Symptoms
IPBES	Intergovernmental Platform for Biodiversity and Ecosystem Services

ABSTRACT

Though the stinging nettle (*Urtica dioica* L.) is categorized globally as an invasive species, the plant is a source of vital nutrients and an ingredient in many local medicine practices. However, there is inadequate information on the edaphic factors enhancing the invasiveness of *U. dioica*, the subsequent impact on local flora diversity, and upcoming value-addition opportunities. Hence, this study sought to determine the invasive effects of *U. dioica* on herbaceous plants density and diversity. Then analyze the relationship between *U. dioica* density with soil mineral contents and investigate the market presence of raw and value-added products. Lastly, this study intended to document local knowledge of *U. dioica* in Nyeri County, Kieni Sub County areas namely; Endarasha, Charity, and Watuka. Sites with high colonization of *U. dioica* were purposively identified. Based on land use types, Stratified random sampling method was used to place five transects each measuring one hundred metres long. Ten quadrats each measuring one square metre in roadside, riverbank, pastureland, residential, and cropland areas were used for data collection. Fifteen soil cores were taken from each land use type and mixed to form soil samples for each land use type in Endarasha, Charity, and Watuka. Questionnaires were administered to 196 respondents from the study area. Results from Pearson correlation analysis between the density of *U. dioica* and other herbaceous species indicated that there was a strong negative correlation between the density of *U. dioica* and other herbaceous species diversity ($r=-0.8$). One-way ANOVA showed significant statistical differences in the concentration of nitrogen ($F=4.8495$, $df=4, 14$, $p < 0.05$) and phosphorous ($F=4.3589$, $df=4, 14$, $p < 0.05$) among different land types confirming their different impacts on *U. dioica* density. The study also established that locally, *U. dioica* is used in the food, medicine, and veterinary sector. Such consumption could indicate the economic potential of the plant species in the local cottage industries to support the government's manufacturing agenda. This study recommends increasing public awareness of the benefits of *U. dioica* to boost its consumption hence reducing its invasiveness.

CHAPTER ONE
INTRODUCTION

1.1. Background

Urtica dioica L. (stinging nettle) is a member of the Urticaceae family and a perennial herbaceous species that originated in Europe and mainly inhabits damp, nutrient-rich, disturbed areas, according to Swearingen *et al*. (2010). This plant is well known due to its stinging hairs on leaves and stems that discharge toxins such as histamine, serotonin, and acetylcholine, which induce pain when contact is made with them. This adaptation helps protect *U. dioica* against herbivory (Taylor, 2009).

In the agricultural sector, ethnobotanical studies have found that the use of *U. dioica* slurry as a fertilizer in horticulture has increasingly been embraced by farmers in countries such as Spain due to its high mineral content (Garmendia *et al*., 2018). According to Disler *et al*. (2014), veterinary reports indicate uses of *U. dioica* in the field of animal nutrition from Austria, Italy, Spain, and Switzerland. Feeding Chickens with *U. dioica* has been found to protect them against endoparasites. Likewise, *U. dioica* has been reported to positively boost metabolic processes in broilers in addition to supporting their immune system, as noted by Hashemi *et al*. (2018). Decoctions made from *U. dioica* and Malva *sylvestris* have been administered to Pigs after calving locally in Italy, aimed at enhancing their immunity to disease-causing microorganisms (Viegi *et al*., 2003). In Canada, *U. dioica* is administered as herbal veterinary medicine to lactating cattle to boost mineral supplements and improve the quality of milk (Lans *et al*., 2007). In accordance with Sapkota *et al*. (2018), the use of *U. dioica* in the control of pests through Integrated Pest Management (IPM) in countries such as Nepal has been found to successfully regulate the effects of pests such as aphids, cutworms, and termites.

All parts of *U. dioica*, that is, seeds, leaves, and roots, are noted to have medicinal value (Jan *et al*., 2017). *Urtica dioica* is useful in the pharmaceutical industry in the manufacture of capsules with a high level of bioaccessibility (Marchetti *et al*., 2018). As a food item, *U. dioica* leaves possess vitamins, fat, protein, carbohydrates, and minerals, as well as trace elements, and are therefore used as vegetables and herbal tea in India (Jan *et al*., 2017). According to Suryawan *et al*. (2017), *U. dioica* natural fiber has potential applications in textile industries as a substitute for pollutant and nonbiodegradable synthetic fibers due to its efficiency, low density, biodegradability, cheapness, and ability to be recycled. Das *et al*. (2015) also reports that, if well utilized, *U. dioica* has a high potential for fiber in textile industries.

In Kenya, *U. dioica* is popular in the Mount Kenya region among the Kikuyu and Meru communities and is commonly used as a traditional vegetable. According to Ndirangu (2015), dried leaves are ground into a powder and used to make porridge flour. At the early stage of development, before stinging trichomes are well developed, both the leaves and shoots of *U. dioica* can be harvested just like other vegetables for cooking purposes (Shonte *et al*., 2017). Sometimes, *U. dioica* is added to mashed food to enrich it with nutrients (Murugu, 2018). Incorporation of *U. dioica* during bread baking has been found to raise the nutritional value of bread due to the addition of minerals such as calcium and iron in addition to fiber content (Maietti *et al*., 2021). As a way of enhancing food sufficiency, there is, therefore, a need to boost the widespread cultivation of organic *U. dioica* (Kregiel *et al*., 2018).

A study by Tarus (2019) on the use of stinging nettle in Nyeri County by both urban and local communities found that 52.9% use the species to treat diabetes as a local medicinal herb, with over 25% using the plant to treat high blood pressure, arthritis, rheumatism, and allergies. *Urtica dioica* herbal tea has been reported to have several health benefits, including lessening symptoms resulting from allergic reactions. Such uses necessitate urgent research on the cultural knowledge guiding this valuable species' medical use in Kenya (Tarus, 2019).

Ecologically, *U. dioica* has been reported as an invasive species with the potential to lower the diversity of other herbaceous species (Xu *et al*., 2019). Swearingen (2010), also notes that in Europe the species pose an ecological threat, especially once established. It smoothers out other herbaceous species by suppressing native species impacting ephemeral spring species and those that crop up during the spring through to the summer. Interestingly *U. dioica* is considered to be nitrophile- (plants that grows well in soil rich in nitrogen) with its growth also being checked by signs of phosphorous deficiency with the remedy being the addition of soluble phosphate form in the soil (Taylor, 2009).

Such global studies reveal a knowledge gap on the local soil characteristics that facilitate this species' invasiveness in the Kieni sub-County. Due to the myriad and the huge invasive potential of this species, it would be beneficial to investigate its impact on the local scale. Hence this study target to look at its invasive impact on local herbaceous plants, management and control measures, soil factors that influence its distribution, and also the local knowledge perceptions of the community towards this species in Nyeri County. In addition, evaluation of available value-addition opportunities to *U. dioica* will target boosting the consumption of *U. dioica* products which will play a great role in managing its invasiveness and associated biodiversity impacts.

1.2 Statement of the problem

Alien invasive species have been reported to have adverse effects on livelihoods, lives, and the natural biodiversity of the colonized lands, according to Jama *et al*., (2005). Some invasive species of most concern in the eastern African region include; *Prosopis juliflora* (Sw.), *Lantana camara* (L.), *and Cryptostegia grandiflora* (Roxb.) (Witt *et al*., 2017).

Like many central Kenya areas, Nyeri County has experienced the biological invasion of *U. dioica*. The presence of *U. dioica* has affected farming and grazing due to irritation by trichomes that release stinging chemicals including histamine. *Urtica dioica* is a fast-growing plant and this leads to competition for nutrients and space with food crops (Kregiel *et al*., 2018).

Figure 1.1: Cropland invaded by *U. dioica* in Kieni Sub County

Urtica dioica has infested moist cultivated areas including, riverbanks, fence rows, and roadsides, and is frequently a weed problem in plantations and residential areas (Schellman *et al.,* 2008*).* In addition to the modification of roots into dense rhizomes, Arthur (2001) noted that the invasive nature of *U. dioica* is also due to high seed production, with those growing under full sun intensity producing ten thousand to twenty thousand seeds per shoot. *Urtica dioica* is also a shade-tolerant species producing abundant seeds of up to five thousand seeds per shoot. These ultimately change the structure of vegetation which unavoidably changes both abiotic and biotic interactions (Saini *et al*., 2014). According to Ian (2014), *U. dioica* invasion is necessitated by its extensive root mass that permits its spread vegetatively once established, often preferring nitrogen-rich habitats. Due to chemicals released by stinging trichomes, the plant creates nuisance environments, especially in urban and residential areas. Despite these adverse effects, there is inadequate information regarding its biodiversity effects on other herbaceous flora, geographical distribution, environmental and socio-economic effects in the Nyeri region, particularly the Kieni area. This study was intended to produce data on the threats posed by *U. dioica* to natural biodiversity and agriculture, management, and control of its spread by farmers, and soil characteristics favoring its dominance, which could potentially shed light on commercial and value addition to the plant.

1.3 Justification for the study

Recent studies prove that *U. dioica* can be used as an alternative medicinal herb against diabetes. Bisrat *et al.,* (2016) argue that *U. dioica* has potential therapeutic value as a natural herbaceous plant with the property of lowering the glucose levels in the blood, therefore some people who have diabetes self-medicate with it as an alternative herb to metformin drug. Said *et al*. (2015) noted that despite the whole plant being used as herbal medicine in Morocco, its medicinal and nutritional data remain poorly explored. Although not fully domesticated, due to the benefits associated with it, the species has remained common especially recently for medicine and food in Nepal and Poland (Said *et al*., 2015). In the study conducted by Safarinejad (2005), to investigate the impacts of treatment with *U. dioica* for the symptomatic reprieve of lower urinary tract symptoms (LUTS) which are secondary to benign prostatic hyperplasia (BPH), it was reported that patients treated with *U. dioica* had improved LUTS by 81% compared with patients who had not been exposed to *U. dioica*.

Rutto *et al*. (2013) noted that regardless of *U. dioica* being renowned as a highly palatable and nutritious vegetable, investigations have concentrated mostly on its medicinal value and as fiber in textile industries. However, *U. dioica* is primarily used as a vegetable when fresh, added to soups to complement dishes, and cooked as a potherb. *Urtica dioica* leaves and roots have a wide range of nutritional benefits, including; Vitamins A, C, and K, and minerals such as calcium, iron, magnesium, phosphorus, potassium, sodium, and Fats (Devkota *et al.*, 2022). Many of these nutrients contribute in boosting body immunity by raising blood antioxidant levels (Amiri, 2016).

Due to irritation associated with handling *U. dioica* with a bare hand, processing the product to a form safe to handle such as powder, while maintaining nutritional value, will increase its consumption as stated by Rutto *et al*. (2013). According to Rutto *et al*. (2013), the use of *U. dioica* when fresh as a vegetable is prevalent. Still, little is known about the potential for its processing for nutritional value.

1.4 Research Questions

1. What are the impacts of *Urtica dioica* density on other herbaceous species density, diversity, and species richness in the invaded areas?

2. Does soil mineral content contribute to the invasiveness of *Urtica dioica* in Kieni West Sub County, Kenya?

3. Is there a difference in the market value of value-added and unprocessed *Urtica dioica* products?

4. What are the local knowledge related to the use of *U. dioica* by the local communities in the Kieni West Sub County?

1.5 Hypotheses

i. The density of *Urtica dioica* does not significantly impact the richness, density, and diversity of herbaceous plant species of the invaded areas.

ii. There is no significant relationship between the density of *Urtica dioca* and the mineral content of the soil in Kieni West Sub County.

iii. Local knowledge on the uses of *Urtica dioica* to local communities does not vary across gender and different age groups

1.6 Objectives

1.6.1 General Objective

To determine the effects of *U. dioica* on biodiversity, assess its market presence, and document local knowledge on its uses by local communities of Kieni Sub County, Nyeri County, Kenya

1.6.2. Specific Objectives

i. To evaluate the impacts of *U. dioica* density on the diversity, density, and species richness of associated herbaceous vegetation.

ii. To establish the relationship between the density of *U. dioica* and the mineral composition of the soil in Kieni West sub-county, Kenya

iii. To assess the market presence of raw and value-added *U. dioica* products in Nyeri County.

iv. To document local knowledge on the uses of *U. dioica* in the Kieni region.

1.7 Significance of the study

The results of this study are important as they seek to identify the negative impacts of *U. dioica* invasiveness on the biodiversity of other herbaceous species which can guide farmers and scientists on the need for control measures. The study also seeks to promote awareness of soil minerals content that promotes the growth *of U. dioica* which can be used as a guide during the cultivation or management of *U. dioica* on farms. The results on the consumption of value-added forms of *U. dioica* as compared to fresh *U. dioica* will be useful in guiding farmers and processing companies in decision-making in focusing on products that may have a longer post-harvest shelf life as compared to fresh and perishable forms of *U. dioica* hence preventing post-harvest losses. This will maximize income generation throughout the year by farmers and boost food security, especially owing to the semi-arid nature of the Kieni region. It will also contribute to the government's Vision 2030 agenda on processing and value addition. The outcome from local knowledge on the uses of *U. dioica* will provide information applicable to the veterinary, medicine, and agricultural sector.

CHAPTER TWO
LITERATURE REVIEW

2.1 Impact of Invasive Species on Biodiversity

Invasive alien flora has long been recognized as an increasing threat to biodiversity, and human health (Simberloff *et al*., 2013). The study by Agoramoorthy, (2007), notes that herbaceous invasive species pose a threat to the biodiversity of other herbaceous flora as well as the economy. Invasive species, according to McGeoch *et al*. (2010), cause biodiversity loss, including species extinctions, changes in hydrology, and ecological function. Invasive herbaceous flora has long been thought to present a threat to biodiversity in terrestrial environments, with decreased species richness and abundance, according to Aravind *et al*., (2010). Biological invasions are also thought to be a direct cause of biodiversity loss, according to Vilà *et al*. (2011), with severe consequences on the diversity, density, and richness of other herbaceous plant species (Vilà *et al*., 2016). Alien invasive flora has the potential to affect native plant abundance, species richness, and variety, as well as ecosystem processes and functions (Ehrenfeld, 2010).

Invasive alien plant species have been noted to be biodiversity threat to aquatic habitats, particularly wetlands, in addition to the terrestrial environment (Ramsar Convention 2018). Invasive biotic invaders have also been associated with causing biota homogeneity on a global scale, thus influencing biodiversity and ecosystem services indirectly (Shackleton *et al*., 2019). According to Kumar, (2000), the spread of invasive alien flora in terrestrial and freshwater wetlands is the major cause of species loss and endangerment in these ecosystems. It has been found that biological invasions by alien invasive plant species have a significant impact on the diversity of related plant community structures in both terrestrial and aquatic ecosystems (Mollot *et al*., 2017). The impacts of invasive plants on diversity, species richness, and density, put the fate of many herbaceous species in jeopardy (Byabasaija *et al.*, 2020).

Invasive alien plant species have presented serious challenges to local biodiversity, ecological services, environmental quality, and human health for several decades (Jones *et al*., 2018). According to studies from the United Nations' (UN) Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES), biotic invaders threaten nearly a fifth of the Earth's surface, (IPBES, 2019), including global biodiversity hotspots (Schmeller *et al*., 2021). As a result, the loss of native plant diversity caused by invasive plants may have an indirect impact on human health due to changes in environmental quality (Jones *et al*., 2018).

More and more, invasion ecology is viewed as a cross-disciplinary problem that is closely tied to changes in land use, and conservation biology, due to the varied detrimental impacts on other herbaceous plant species (Heshmati *et al*., 2019). Assessment of the impact of invasive species to herbaceous species richness and diversity will contribute to positive biodiversity effects, which are critical for accomplishing the Sustainable Development Goals (SDGs) of food security and environmental conservation (Hejda *et al*., 2009). Invasive plant species are one of the most serious challenges to long-term biological diversity protection in both terrestrial and aquatic ecosystems (Lee *et al*., 2016). The establishment and spread of invasive plant species can have disastrous effects on populations, communities, and ecosystems, according to Parker *et al*., (2013).

Disturbance-driven alien invasive species expansion is usually connected to poor native herbaceous flora performance, which leads to reduced species diversity, resulting in irreversible changes in the species composition of herbaceous plants (Navarro *et al*., 2018).

High nutrient content in both aquatic and terrestrial ecosystems has been associated with invasive alien plant species' success in new habitats (Uddin *et al.*, 2014); for example, higher nitrogen in soils helps *Bromus tectorum* (Annual Cheatgrass) outcompete native flora (Uddin *et al*., 2014; Morris *et al*., 2016). Globally, new invasive alien plant species are expected to form as a result of ongoing anthropogenic disruptions (Seebens *et al*., 2018).

2.2 Socioeconomic impacts of invasive species

The spread of alien invasive plant seeds and specimens is associated with construction of forest roads, through the movement of contaminated soil and construction materials (Muscolo *et al*., 2014). A study by Kueffer, (2017) noted that anthropogenic disruptions are a major contributor to the global spread of invasive alien plant species, as well as drastically altering the invasion mechanisms.

Several invasive alien plant species that were introduced for human benefit have been known to cause havoc on the environment and the economy (Souza *et al*., 2018). For instance, the spread of *Opuntia stricta* (Erect prickly pear) throughout Africa including arid and semi-arid areas of Kenya such as North Eastern region, has a negative impact on the environment and the economy. It has also had an impact on local people's livelihoods due to reduced pastures and effects on the health of livestock (Shackleton *et al*., 2017). It has been reported that alien invaders cause an annual economic loss in the agricultural sector of African countries by inflicting damage to farm crops (Sileshi *et al*., 2019). According to Rai *et al*. (2018), the spread of alien invasive species has increased as a result of modern intensive agriculture aiming at enhancing food security.

A study by Codling *et al*., (2014) found that *U. dioica* has the ability to absorb heavy metals such as arsenic and lead from the soil hence can be applied in the sequestration of heavy metals from the soil. Invasive alien flora has also been linked to soil erosion which consequently reduces the production of food crops (Pejchar *et al*., 2009). Invasions by noxious invasive alien plant species such as *Centaurea stoebe*, (Spotted knapweed) *Euphorbia esula* (Leafy spurge), and *Bromus tectorum* (Cheatgrass) are considered to have a negative impact on food production once established due to competition with food crops and lowering soil fertility quality (Gibbons *et al*., 2017). In addition, studies have proved that biological invasion reduces the growth of food crops (Alderman *et al*., 2019), hence resulting in negative socioeconomic and health consequences (Roy *et al*., 2019). The spread of invasive alien species on a worldwide scale, particularly in disturbed places like dump sites, can have a significant impact on human health due to their pollen and poisons (Plaza *et al*., 2018).

Protecting native plants from invasive species is critical due to their role in carbon sequestration hence contributing to a conducive ecosystem (Shackleton *et al*., 2019).

Some researchers have linked allergies caused by invading alien plant species to be a global health challenge (Lake *et al*., 2017). Even though invasive alien plant species are linked to negative biodiversity consequences, it should be recognized that not all invasive alien plant species pose harm to the environment (Young *et al*., 2011). Even though several invasive alien plant species have been associated with negative biodiversity impacts, (Singh *et al*., 2020), some serve as nutrients for the green economy, animal feed, bio-polymers, and bio-energy (Rai *et al*., 2020). The sustainable use of invasive alien plant species for the production of biofuels, such as *Eichhornia crassipes* (Mart.) (water hyacinth) and *Phragmites australis* (Reed)(cav.), may fulfill the dual aims of management of exotic weeds and sustainable renewable energy (Stabenau *et al*., 2018).

On one hand, certain invasive alien plant species provide food, but on the other, they reduce the yield of agriculturally vital food plants (Shackleton *et al*., 2019). Even though the Australian Acacia plant species is an invasive foreign plant species in Africa and Madagascar, it is also employed as a source of income for many poor families (Shackleton *et al*., 2019). Other invasive alien plant species common in Kenya include *Opuntia ficus-indica* and *Prosopis juliflora*. These species have thorns which injure both livestock and human beings especially in arid and semi-arid areas of Kenya such as Baringo (Shackleton *et al*., 2019).

According to Sekar *et al*. (2015), creating a plan for effective management of invasive species control, as well as increasing understanding of their diversity and applications, is critical. To address the present and future potential threats posed by biological invasions in the context of climate change, there has been a substantial international and national policy response aimed at regulating the spread of invasive species (Turbelin *et al*., 2017).

As a possible danger to native biological diversity, invasive alien species must be managed to ensure that all herbivores have enough food and that productivity is maximized according to Adcock *et al*. (2017). Biodiversity has been recognized as the source of food security around the world as noted by Jones, (2019). The control of invasive alien species' consequences on ecosystems and public health has been a top priority of the Convention on Biological Diversity (CBD), which is emphasized further through Biosafety and the Cartagena Protocol (Pysek *et al*., 2012).

2.3 Description of *Urtica dioica*

Ecologically, *U. dioica* is an invasive species belonging to the family Urticaceae (Xu *et al*., 2019). One of the recognizable features of this plant is serrated and hairy leaves that sting (Kregiel *et al*., 2018). The sting is attributed to the release of fluid containing stinging chemicals, including histamine and serotonin, which act as *U. dioica's* defense mechanism against herbivory (Erland *et al*., 2017). In habitats where mammalian grazing is intense, *U. dioica* is designed with numerous trichomes acting as a defense against grazing (Mortensen, 2013). Some of the unique features of *U. dioica* are opposite leaves which portray an oval shape with a thin, and dark green color (Baumgardner, 2016). The leaf margins are serrated, with the surface of leaves and stem being covered by stinging trichomes (Kavalali, 2003).

During the early stage of leaf development, *U. dioica* posses pointed stipules at the petioles of the leaves which dry during later stages of leaf development (Baumgardner, 2016). The plant has green erect stems. It grows tall reaching a height of approximately three feet. The cross-section of stinging *U. dioica* stems portrays a slender, square-shaped stem (Baverstock *et al.,* 2011). The flowers are either yellow or white (Figure 2.1). The plant produces anemophilous flowers between May and October and occasionally the flower is pollinated by moths, birds, or insects which enhance its reproductive success and hence its invasiveness. (Ahmed, 2016). *Urtica dioica* possesses thin, branching spikes on the leaf axils, with tiny, green-white flowers clustered in groups. On the same plant, male and female clusters of flowers develop, although typically from distinct leaf axils (Parsuraman *et al*., 2014).

The grayish dry fruit of *U. dioica* is tiny, oval in shape, and contains one seed. Fruits are grouped along loose flower spikes (Baumgardner, 2016). On a single plant, mainly growing under adequate light intensity, more than twenty thousand seeds can be generated. The seeds have minimal to no dormancy and remain affixed on the spikes until they are blown by wind for dispersal. Since the seeds lack dormancy, germination may take place right away after dispersal, provided favourable conditions for germination are available (Parsuraman *et al*., 2014)

Figure 2.1: Mature *U. dioica* plant in Kieni Sub County from Endarasha 2021

Rhizomes of *Urtica dioica* form a thick below-ground network that aids in the plant's proliferation. The well-developed root system of *U. dioica* with rhizomes allows it to create thick colonies that are exclusive to many other species, contributing to its invasiveness. It is challenging to eradicate an established colony of *U. dioica* since the subsurface structure grows annually and cannot be controlled by mowing, according to Loux *et al.* (2017). *Urtica dioica* can grow and spread among other herbaceous flora, including legumes. It is believed that *U. dioica* will last for about fifty years. Through repetitive tillage and cultivation over several years, some control may be attained (Loux *et al.*, 2017)

The roots are modified with rhizome, reaching depths of about 30 cm, which enables *U. dioica* to spread vegetatively and often form dense colonies. On very fertile soils, *U. dioica* forms a thick canopy even in the early stages of growth and development; this prevents other herbaceous plants from accessing maximum sunlight (Taylor, 2009). The tap root system of *U. dioica* is composed of fine rootlets, that maximize the absorption of water and mineral salts (Joshi *et al*., 2014).

U. dioica differs morphologically from other species in the Genus *Urtica* that are found in the central Kenya region, like *Urtica massaica*. For example, *U. dioica* leaves are narrower than *U. massaica* leaves. Furthermore, Unlike *U. dioica*, *U. massaica* is taller, growing to a height of almost 2 metres. Moreover, *U. massaica* is native to Africa, where it grows in Congo, Burundi, Rwanda, Kenya, Uganda, and Tanzania, in contrast to *U. dioica*, which is native to Europe. (Nduwamungu *et al*., 2024)

2.4 *Urtica dioica* invasiveness

An invasive species is an introduced plant flora that becomes overpopulated once established and grows rapidly, forming homogenous dominant vegetation that excludes other herbaceous species in an ecosystem (Davis *et al*., 2000). Originally *U. dioica* was native to Europe, and western North Africa. *Urtica dioica* is believed to have been introduced in Kenya during roads construction due to global travel in the nineteenth century (Blegen, 2017). It was used traditionally in the treatment of skin infections by indigenous people, according to Cummings *et al*. (2011). Like other invasive plant species, once established, *U. dioica* colonizes farms, particularly wheat, oats, barley, and other food crops, according to Bayer CropScience, (2015). This is due to the spread of rhizome, which allows it to create dense colonies that keep out other species. Because of their quick growth and soil covering, *U. dioica* is considered an invasive weed (Kregiel *et al*., 2018). Mechanical control of *U. dioica* invasiveness by human activities has been rendered difficult due to its nuisance of stinging hairs on leaves and stems (CABI. 2014.)

The study by Adhikari *et al*. (2016), also notes that stinging hairs on stems and leaves of *U. dioica* are some of the reasons for the difficulty in eliminating the species from croplands. Eradication of *U. dioica* has also been rendered difficult in most instances since below ground root system persists even after above-ground biomass has been eradicated (CABI. 2014). Globally, *U. dioica* invasion not only poses a threat to other herbaceous flora but becomes a nuisance, particularly in residential and urban areas due to its associated stinging property (CABI. 2014). A study by Power *et al*. (2020), found that the existence of *U. dioica*, even at the seedlings stage, hinders the invasion success of other herbaceous species. *Urtica dioica* is the only species that reduces the growth of *Impatiens glandulifera* which is also an invasive species according to Jeschke, (2014). Invasive alien species pose a significant threat to biodiversity, which is associated with increased global travel and trade (Vila' *et al*., 2011). A study by Jankauskienė *et al.* (2015), found that the productivity of other herbaceous species was reduced with the invasion of *U. dioica.*

2.5 *Urtica dioica* habitats

Urtica dioica is a herbaceous wild plant in the Urticaceae family and, Genus *Urtica* that is found throughout Europe, Asia, America, and parts of Africa and has adapted to a variety of climates (Di Virgilio *et al*., 2015). *Urtica dioica* is abundant in the Pacific Northwest, particularly in areas with heavy annual rainfall (GBIF, 2015). *Urtica dioica* is a perennial plant that grows mostly in the wild and on farms, according to Repajić *et al*. (2021). It has been noted that *U. dioica* is a versatile plant in terms of native habitat and climate. It thrives in moderate to temperate regions, preferring open or partly shady settings with an abundance of moisture, such as woodlands, rivers or streams, and along roadside ditches (Kregiel *et al*., 2018). In Kenya *U. dioica* is widespread in areas including rift valley and central Kenya regions. (Wambui *et al*., 2024). *Urtica dioica* grows in temperate climates with altitudes of up to 1800 meters in cooler parts of Europe, North America, and Africa (Grauso *et al*., 2020). The species is well adapted to both light and shade habitats, and it has chemical defenses in various habitats that aid in its survival under various biotic and abiotic conditions. This determines the quality in terms of a plant's defense mechanisms (Lee, 2016). *Urtica dioica* is native to northern Europe and Asia, where the environment is cooler. Throughout the year, *U. dioica* generates new shoots from rhizomes and stolons for perennation (Jakauskien *et al*., 2015). According to a study by Inderjit *et al*. (2017), *U. dioica* is more common along rivers and has a higher ground cover in comparison to native plant species, which is facilitated by favorable environmental circumstances. Despite the multiple benefits of *U. dioica*, it is primarily harvested in the wild. In accordance with Upton (2013), countries with major production of *U. dioica* include; Eastern Germany, the former Soviet Union, Bulgaria, Yugoslavia, Hungary, and Albania.

2.6 *Urtica dioica* soil nutrient requirements

The abundance of *U. dioica* in a habitat is influenced among other factors; mineralization of the soil. These nutrients include nitrogen, phosphorus, calcium, magnesium, Zinc, Copper, and Manganese. The experiments on minerals regulating the growth of *U. dioica* have found nitrogen and phosphorous to have greater effects on the total dry mass of the plant (Taylor, 2009). *Urtica dioica* has often been classified among nitrophile plants, with its growth also being checked by the deficiency of phosphorous unless soluble phosphates are added to the soil (Taylor, 2009). According to Pierre *et al.* (2019**),** one striking feature of black cotton soil is its dark clay color, forming very compact and opened cracks during dry conditions. Black cotton soil has moderate natural soil fertility. Red soil has been categorized among the most agricultural productive soils with Ethiopia and Kenya having the highest levels of red soil among tropical African countries (Pierre *et al.,* 2019**)**. Red soil has a high ability for absorption and adsorption of phosphorus and allows root penetration deep into the soil thus helping in reducing soil erosion (FAO 2001).

2.7 Economic importance of *Urtica dioica*

Urtica dioica is used in curries, sour soups, vegetable side dishes, and other dishes. It also provides a wide range of medical benefits, including relief from arthritis, rheumatism, and muscular pain (Adhikari *et al*. (2016). *Urtica dioica* harvested from leaves and stems are useful in making fiber (Di Virgilio *et al*., 2015). It has also been noted that *U. dioica* has a long history in New Zealand as a source of fiber, food, and herbal medicine. *Urtica dioica* fibers are used for textiles in addition to hemp (*Cannabis sativa L.*) and flax (*Linum usitatissimum L.*) (Hartl *et al*., 2002). According to Baverstock *et al*. (2011), *U. dioica* can create high-quality fiber that can be used in the textile industry. Nettles were utilized to produce textiles in Germany and Austria during World War One owing to their high amount of strong fibers (Adhikari *et al*., 2016). *Urtica dioica* is grown in Sweden for its fiber, which is used to make cottage and sailcloth. Nettle cultivation is very similar to flax cultivation (Tacklind *et al*., 2009).

Urtica dioica is a perennial wild plant that offers nutrients for aphid natural enemies, which can help in the biological protection of crops (Adhikari *et al*., 2016). A research study by Ngugi *et al*. (2015) found that *U. dioica* can be used as a feed additive to improve sustainable aquaculture. The efficacy of *U. dioica* as a dietary supplement can increase the growth and nonspecific immunity of fish (Ngugi *et al*., 2015). *Urtica dioica* improves soils that have been over-fertilized with nitrogen and phosphate primarily due to its tendency to absorb these soil nutrients (Upton *et al*., 2013). According to several ethno-botanical studies, Spain is increasingly using *U. dioica* slurry as fertilizer for the cultivation of organic horticultural crops (Latorre, 2008).

Scientific investigations have shown that *U. dioica* has anti-inflammatory and anti-bacterial qualities, as well as the ability to relieve stomach pain (Ankarcrona, J. 2019). *Urtica dioica* has long been used to treat cardiovascular problems, including hypertension. Similarly, *U. dioica* leaf extract has been shown to enhance glucose homeostasis. Nettle root has the potential to alleviate some of the symptoms of prostatic hyperplasia (Dhouibi *et al*., 2019). According to Bisht *et al*. (2012), the benefits of *U. dioica* as a therapeutic herb outweigh the risks of using it as a weed. According to the research by Kregiel *et al*. (2018), *U. dioica* can be used to treat a variety of conditions, including asthma, rheumatism, and sciatica. In accordance with Adhikari *et al*. (2016), *U. dioica* contains a wide range of therapeutic properties, including relief from arthritis, rheumatism, and muscular pain.

Urtica dioica has wide applications in the food, medicine, and cosmetic industries according to Di Virgilio *et al*. (2015). *Urtica dioica* has a high nutritional value as compared to other vegetables and is often more nutritious than other common garden herbs according to Zeipiņa *et al*. (2014). *Urtica dioica* is a popular green vegetable in many parts of the world due to its high protein, crude protein, and crude fiber content (Ahmad *et al*., 2007). When *U. dioica* is processed, such as cooked, blanched, dried, or ground, it no longer stings and can be used as a meal (Carvalho *et al*., 2017). Because of its sting, *U. dioica* is rarely domesticated, yet it is nevertheless used as food and medicine in destitute countries like Nepal (Uprety *et al*., 2012). In Georgia, cooked *U. dioica* with walnut seasoning is a popular dish. Green nettle leaves plucked from young plants are combined with fermented wheat bran vegetables to form a sour soup (Costa *et al*., 2013). *Urtica dioica* is a common wild edible plant (WEP) that can be used as a staple or supplement diet. These WEPs are frequently the primary source of financial income for local communities, contributing to regional food security (Adhikari *et al*., 2016). Organic food intake such as *U. dioica* has been linked to positive health perceptions and subjective well-being, as well as increased market value and demand (Apaolaza *et al*., 2018). *Urtica dioica* is a perennial herb that has important traditional therapeutic benefits in several countries, according to Jankauskien *et al*. (2015). The leaves are also known to contain high levels of important metals such as selenium, zinc, iron, and magnesium (Kregiel *et al*., 2018). Research study has found fresh *U. dioica* leaves to be rich in vital Vitamins including; vitamins A, C, D, E, F, K, and P (Rutto *et al*.,2013).

The summary of the economic significance of *U. dioica* in Table 2.1 highlights the study by Kregiel *et al*. (2018), which documented that extracts from *U. dioica* root can lower the risks of cancer cells in the prostate gland, in addition to self-medication for bladder infections. According to Said *et al*. (2015), *U. dioica* leaves have high sugars, fat, protein, and minerals. In addition to being rich in phosphorus, calcium, magnesium, zinc, iron, and potassium, freshly growing *U. dioica* shoots are usually harvested before producing flowers and used as a spinach alternative (Rutto *et al*., 2013). *Urtica dioica* is used in the cosmetic industry as an anti-aging complex due to its ability to hinder collagenase and elastase enzymatic activities, as noted by Bourgeois *et al*. (2019). In describing the use of plant powders as food additives Kregiel *et al.* (2018) noted that extracts from *U. dioica* leaves and oat are used as ingredients in beverages or fruit juice to provide nutritional drinks in America. To enhance poultry and pig farming in Poland dried leaves from *U. dioica* are used as a traditional food for pigs and improve the quality of eggs through the yellowing of egg yolk in poultry.

Table 2. 1: Summary of the economic significance of *U. dioica*

NETTLE USE	PART OF PLANT	PREPARATION	TARGET FOCUS	REFERENCE
1. Medicinal	Leaves	Tincture	Diabetes Allergic rhinitis Acute arthritis	Said *et al.*, 2015 Rutto *et al.*, 2013
	Flowers	Infusion	Tuberculosis and kidney stones	Kregiel *et al.*,2018
	Roots	Decoction	Acts against prostate cancer cells	Said *et al.*, 2015
	Seeds	Decoction	Acts against prostate cancer cells	Kregiel *et al.*,2018
2. Food	Leaves	Steaming	Source of minerals, fat, vitamins, carbohydrates, and trace elements Bread making, Herbal tea, Alcoholic beverage, Nutritional drinks Meat tenderization	Said *et al.*,2015 Kregiel *et al.*, 2018
	Roots	Marinating	Anti-aging complex	Bourgeois *et al.*,2019
3. Cosmetics	Leaves	Tincture	Anti-aging complex	Kregiel *et al.*,2018
4. Feed suppleme nt	Fresh leaves	Drying	Traditional food for pigs and yellowing of egg yolk in poultry farming Forage crop for cows Making silage for lactating cows	Kregiel *et al.*,2018

2.8 Traditional use of *Urtica dioica* in Kenya

According to Munene, (2020) cultivation of *U. dioica* has risen significantly due to increased consumption by the health-conscious middle class. Value addition to nettles has been found to add more income with a bundle of Ksh10 (USD 0.07) nettle leaves in the local market fetching up to Ksh50 (USD 0.4) when ground into powder due to diverse uses such as making porridge and chapati (a flatbread of Indian origin made by mixing wheat flour and water to make dough) as noted by Munene, (2020). The leaves of *U. dioica* are used to prepare traditional food such as mashed beans, maize, and potatoes locally known as *mukimo*. When grounded in powder form, *U. dioica* has a broader market and is sold throughout the year as compared to fresh leaves (Muthoni, 2009). A study by Tarus *et al*. (2019) on the traditional use of stinging nettle found that 90% of urban dwellers in Nyeri County extract the plant for domestic use. Their findings showed; that stinging nettle was majorly used for medicinal and food functions with a higher administration of nettle products such as nettle herbal tea compared to nettle soup (Tarus *et al*., 2019)

2.9 Summary of Knowledge Gaps

Further research on *U. dioica* uses, including possible large-scale exploitation of the herb for medical and food supplement purposes in Kenya, stems from several recommendations by scientists as described in appendix 1. In the study by Taylor, (2009) it was found that *U. dioica* develops into a thick canopy on soils with high fertility during the early stages of development which prevents other herbaceous plants from accessing maximum sunlight. The knowledge gap identified in this study is the factors that check the growth of *U. dioica.*

According to a study by Lockton *et al*. (2015) in Britain, the invasive nature of *U. dioica* is due to high seed production, which establishes itself in areas previously occupied by other invasive weeds. Consequently, this reduces species diversity and subsequent formation of pure stands of *U. dioica;* therefore need to investigate the role of *U. dioica* in biodiversity.

According to Said *et al*., 2015, products from powdered *U. dioica* leaves are rich in protein, fat, carbohydrates, vitamins, minerals, and trace elements and are used in Morocco as food. Therefore need to assess its market presence which can guide *U. dioica* value addition and processing.

CHAPTER THREE
MATERIALS AND METHODS

3.1 The Study Area

The study sites were drawn from three sub-locations from Kieni Sub-County in Nyeri County, namely, Endarasha, Charity, and Watuka (Figure 3.1). Kieni Sub-County lies between Longitude of 10 16' 46.111" N and Latitude 360 47' 25.665" E (Figure 3.1). The area covers approximately 817.1Km^2 square kilometres and has a population of about 198,901 (Kieni East 110,376 and Kieni West 88,525) persons (KPHC 2019). Due to the low annual precipitation of 500 mm in the Kieni region, the place is classified as semi-arid. The area is also characterized by a dry and hot climate with low and unpredictable rainfall varying commonly across time and space. Kieni region has bimodal rainfall patterns where short rains occur around October or November, and long rains are experienced in March or April (Maina *et al*., 2020).

The total land cover of both Kieni East and West is fifty-two percent of Nyeri County. The majority of the people engage in mixed farming, agro-pastoralism, and formal, and non-formal employment (Figure 3.2) (Mutunda *et al.*, 2017). The main river channels in this region include the river Mwiyogo and Ngaring'iro River. The area is dominated by black cotton soils largely in Endarasha, with farmers participating majorly in the growth of maize, Irish potatoes, and onions as a cash crop, while Watuka and charity are dominated by red soils, with farmers mostly growing cabbage, and carrots in addition to maize (NAAIAP, 2014). Soil pH in the Kieni sub-county varies from moderately alkaline (8.1) to moderately acidic (5.2). Major soil types in the Kieni region include; black cotton and red soil (NAAIAP 2014). Watuka and Charity, being close to Aberdare ranges experience rainfall more often than Endarasha, and therefore the latter was chosen to act as a control.

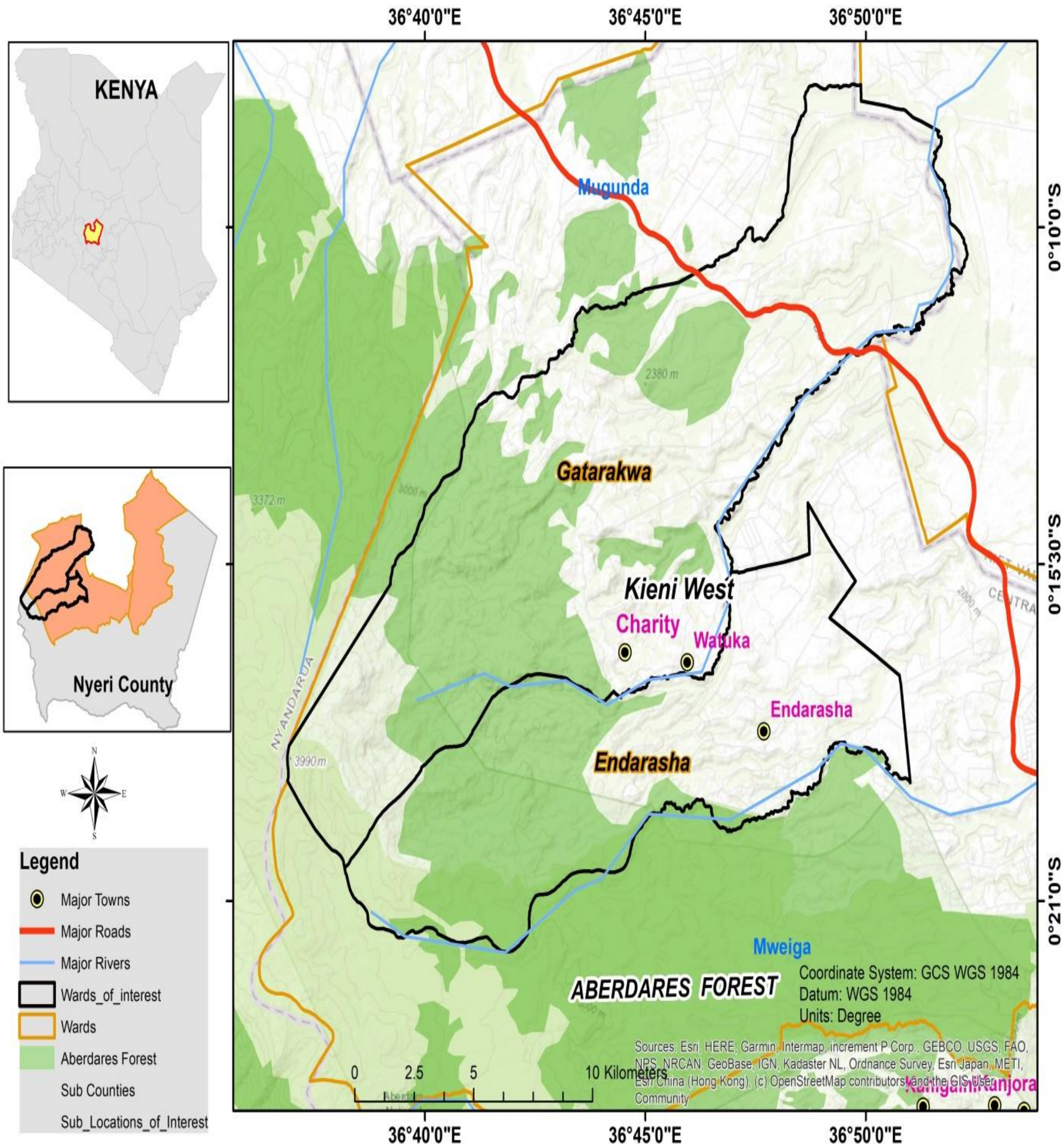


Figure 3.1: Map of the Study Area (source; Nyeri Kieni County LRA 2019 Report)

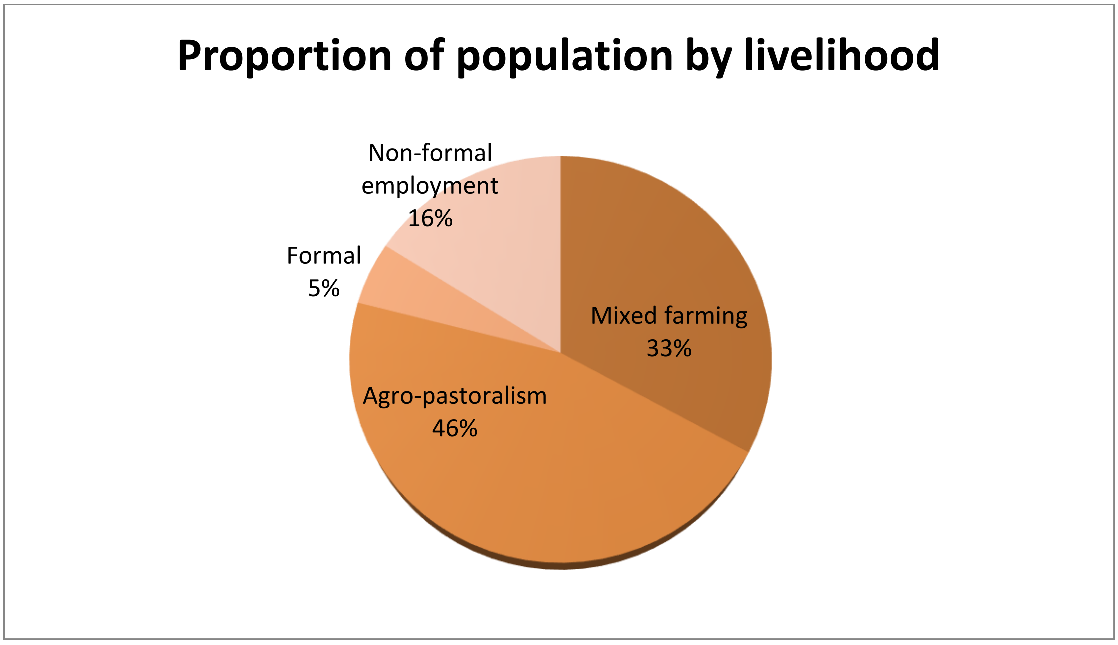


Figure 3.2: Proportion of the population by livelihood (Source: IEBC, 2019)

3.2 Research Design

The survey was carried out from April 2021 to December 2021 in the three sub-locations of the Kieni West sub-county, namely; Endarasha, Charity, and Watuka. These sites were chosen based on a reconnaissance survey which found *U. dioica* to occur predominantly across several land-use types, such as cropland, pastureland, and riverbanks. The selection of study sites was also guided by the extent of biological invasions of *U. dioica* in these sites. The three regions have varied climatic zones with Watuka and Charity neighboring Aberdare ranges to the West and therefore forming highly productive agricultural areas, while Endarasha forms semi-arid agro-ecological zones to the East (Figure 3.1).

This study consisted of four stages: sampling for herbaceous plant species, soil analysis in areas with the presence of *U. dioica*, assessment of the market presence of raw and value-added *U. dioica*, and documenting local people's local knowledge about *U. dioica*.

Due to large clusters of *U. dioica* identified during the reconnaissance survey, stratified random sampling was used to locate sampling sites based on the presence of *U. dioica*. This was accomplished through observation in identifying areas with homogeneity about *U. dioica*. Land use types sampled include; croplands, riverbanks, roadsides, residential areas, and pasturelands. A stratified sampling method was used to sample the sellers of *U. dioica*. Through market heads and research assistants, the established sellers of *U. dioica* were identified from the markets. This was useful in ensuring only the sellers of *U. dioica* were interviewed. According to Taherdoost (2016), stratified sampling is often used where there is a great deal of variation within a population since it is highly unbiased. Single-stage cluster sampling was used to identify households from villages in Watuka, Endarasha, and Charity for the study. This was guided by visual observation from a reconnaissance survey on villages that had encountered invasion of *U. dioica*. The data on local knowledge about *U. dioica* was obtained from household heads comprising 98 men and 98 women through questionnaires. Research assistants were used to interpret research questions for the respondents. According to Rapp *et al*. (2019), cluster sampling has high external validity since the sample selected reflects the characteristics of the entire population.

3.2.1 Effects of *U. dioica* density on other herbaceous species diversity, density, and richness.

A stratified random sampling method was used to delineate areas with *U. dioica* from the following land-use types: roadside, riverbank, pastureland, residential, and cropland. Each land use type selected was more than one hectare, based on the presence of *U. dioica*. Once the sampling site was set, a hundred-meter-long transect was established, from which ten quadrats were systematically placed in equidistant positions along the transect.

Urtica dioica and other herbaceous plant species were identified, counted, and recorded using the datasheet. These data were used to conclude the impacts of *U. dioica* density on the diversity, density, and richness of herbaceous vegetation.

$$Density = \frac{Total\ number\ of\ all\ individuals\ of\ species\ in\ all\ the\ quadrats}{Total\ number\ of\ quadrats\ studied}$$

S= Species richness = Number of species counted per given unit area

Shannon-Wiener diversity Index

$H = -\sum(pi) \times \ln(pi)$

Where;

pi = Proportion of total sample represented by species i. Divide by no of all individuals of species samples (Nolan, *et al*., (2006).

3.2.2 Determination of the effects of abundance of *U. dioica* in relation to minerals content of the soil in Kieni West Sub County, Kenya

During soil sampling, only the areas with similarities in physiognomies in relation to presence of *U. dioica* were chosen (Muriuki, 2001). Among the areas that were avoided during soil sampling include; the fence, refuse lines, or where waste materials were burnt lately. These areas are usually composed of high levels of mineral elements and they may not give reliable data.

From the transect selected in objective one, a zigzag pattern was used to collect soil samples (250g) from ten quadrats in cropland. Fifteen soil cores were taken from each land use type and mixed to form soil samples for Endarasha, Charity, and Watuka. According to Scrimgeour, (2008), the zigzag sampling pattern is suitable for field sampling as only one sample from each field is sent for laboratory analysis, making the technique less time-consuming and inexpensive. A soil auger was used in soil scooping at 0-30cm depth and samples were mixed thoroughly. One soil sample of two fifty grams was obtained and labeled for laboratory soil analysis. The above procedure was repeated for the other land types selected namely; pastureland, roadside, riverbank, and residential. The soil collected was transported to Kenyatta University Chemistry Laboratory for analysis of soil mineral content using the procedure by Okalebo *et al., 2002.*

3.2.2.1 Preparation of soil samples for analysis of N and P

Digestion of the soil samples was conducted using an electric hot plate and conical flasks. A mass of 250g soil samples from different land types was oven-dried at 70^{o}c for 4 hours. 0.3 ± 0.001 g of oven-dried soil sample was weighed and placed into a labeled dry clean 125 ml Pyrex conical flask. 4 ml concentrated sulphuric (VI) acid was added and swirled carefully to ensure that the entire sample was wetted. The mixture was heated in a fume cupboard, using an electric hot plate set at "medium" heating. The flasks were then cooled, followed by the addition of 10 drops of hydrogen peroxide slowly at a time, to avoid a vigorous reaction of the contents.

The flasks were then Swirled and further reheated, avoiding excessive heating that could lead to spattering. The mixture was then cooled, 6 drops of hydrogen peroxide were carefully added, and reheating continued. Continuous cooling and adding of 6 drops of hydrogen peroxide until there was a change of color, from black to dark brown was done. Once the brown color was observed the heater on the hot plate was turned on to a 'high' setting. Cooling while adding 6 drops of hydrogen peroxide, and heating was done until the solution turned colorless on cooling. Then hydrogen peroxide was added and the mixture was left for the last time on a 'high' burner for 15 minutes. The contents of the flasks were cooled and transferred quantitatively into a 50 ml volumetric flask, using distilled water. The contents were brought to the mark with water after cooling. From these contents, the analysis of Phosphorus and Nitrogen was determined.

3.2.2.2 Preparation of Nitrogen stock and standard solutions

Stock solution for nitrogen (2500 mgN/liter) was prepared by dissolving 11.793g of ammonium sulphate in a 1000ml volumetric flask followed by topping up to the mark with distilled water. From the stock solution, 0, 2.5, 5.0, 7.5, 10.0, and 15.0 mgN/litre standard solution of nitrogen were prepared. Using a UV spectrometer, the results of absorbance of the standard solutions were used to draw a calibration curve (appendix 2) of known concentrations of nitrogen solutions that were later used to determine the concentration of nitrogen from the samples.

3.2.2.3 Preparation of Phosphorous stock and standard solutions

The stock solution of 1000 ppm P phosphorous was prepared by dissolving 1.0967g of oven-dried potassium orthophosphate in a 250 ml volumetric flask and made up to the mark with distilled water. From the stock solution, 0, 1, 2, 3, 4, and 5 ppm standard solutions of phosphorous were prepared. Using UV spectrometer, the results of absorbance of the standard solutions were used to draw a calibration curve (appendix 2) of the known concentration of phosphorous solutions that were later used to determine the concentration of phosphorous from the samples.

3.2.2.4 Analytical Outcomes of UV/visible spectrophotometry for Nitrogen and phosphorous

The absorbance and concentrations of the standards were used to plot the calibration curves. The standard solutions prepared from stock solutions were used to establish UV/visible calibration curves and in turn, used to determine the concentrations of a selected analyte in soil samples. From the results presented in Table 3.1, it can be concluded that the linearity of the established calibration curves is good, hence accurate measurements were guaranteed.

Table 3.1: Analytical Outcomes of UV/visible spectrophotometry for Nitrogen and phosphorous

Analyte	**Wavelength (nm)**	**Linearity(r^2)**	**Equations for the calibration curve**
Nitrogen	650	0.956	y = 0.0493x + 0.0727
Phosphorous	400	0.9783	y = 0.0819x + 0.0552

y: absorbance; x: concentration

The concentration (mg/litre) of nitrogen and phosphorous results were recorded in Table 4.3.

3.2.3 Assessment of the market presence of raw and value-added *U. dioica* products

Evaluation of the market presence of value-added products and raw forms of *U. dioica* was accomplished through interviews. To ensure only the sellers of *U. dioica* were interviewed, a stratified sampling technique was used to sample subjects for data collection.

Through market heads and research assistants, the established sellers of *U. dioica* were identified from the markets. Through the census, 100% of the sellers of *U. dioica* encountered were interviewed. The data were collected from markets in Nyeri County's major towns, including Karatina town, Chaka town, and Nyeri town. The interview guide consisted of questions focusing on; the name of products in which *U. dioica* has been incorporated, the most popular *U. dioica* products preferred by consumers, their presence in the market, and examples of value-added forms of the herb. Interviews were conducted with the assistance of market heads, and research assistants, who were retailers of *U. dioica*-related products. An interview guide was used for that exercise.

3.2.4 Local knowledge of the uses of *U. dioica* in local communities.

Based on the age and gender of members of different households, local communities were surveyed using the questionnaire to obtain information on the uses of *U. dioica* as food, feed supplements, herbal medicine, abundance, rainfall requirements, and phenology. Based on the population of the study area (110,376), single-stage cluster sampling was used to identify households from villages in Watuka, Endarasha, and Charity for the study. The data on local people's local knowledge about *U. dioica* was obtained from household heads comprising 98 men and 98 women through questionnaires.

During the sampling process, different age groups were included to accommodate the views of both youths and older members of society since they may have different perceptions of the use of medicinal plants such as *U. dioica*. Where possible, household heads were interviewed since they are known to make key decisions concerning the use of medicinal plants such as *U. dioica* for various purposes. Their presence in the study area, based on their age, makes their experience often acknowledged by the other members.

The sample size was calculated using Fisher's equation. According to Jung (2014), Fisher's equation is suitable for determining even population size where the population is heterogeneous.

$$N = \frac{t2 \times p(1-p)}{m2}$$

Where;

n=sample size

t=confidence level of 95%

p= proportion of the target population with the desired characteristics.

m= margin of error at 5%

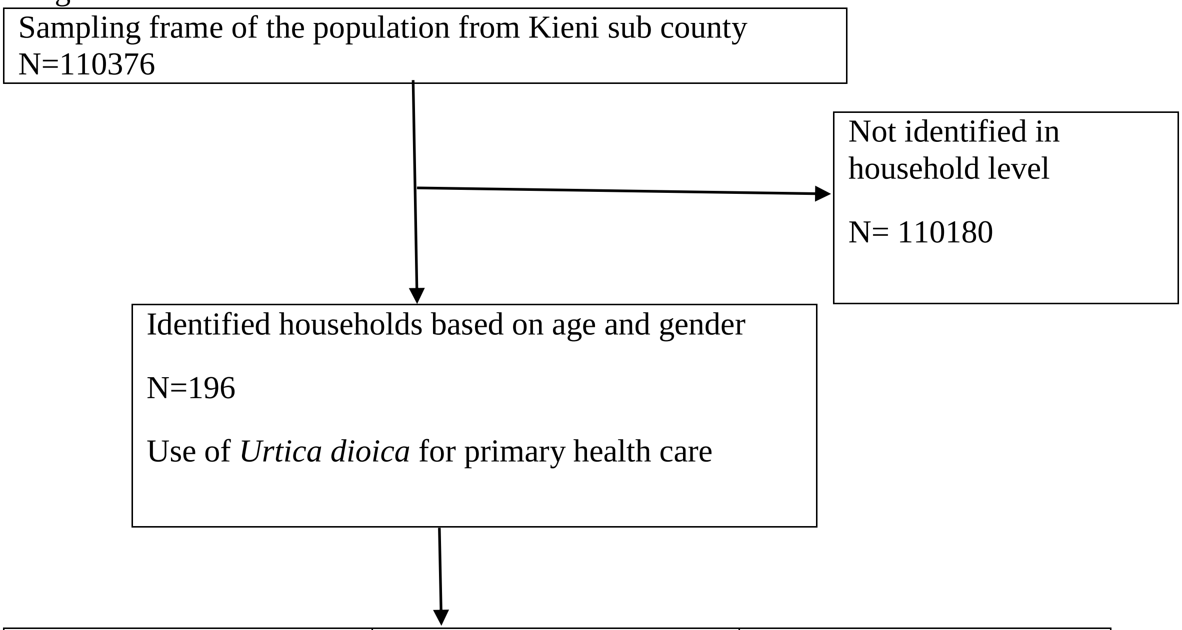
Calculation;

$$N = \frac{1.962 \times 0.85(1-0.85)}{0.05}$$

N=196

Table 3.2 illustrates a sampling frame showing distribution of respondents among the various categories of respondents sampled, to determine the local knowledge of the uses of *U. dioica* by local communities in kieni region.

Table 3.2: Sampling frame showing distribution of respondents among the various categories



Age	Male	Female
19-29	17	06
30-39	21	13
40-49	07	15
50-59	20	23
60 and above	33	41
Total	98	98

3.3 Data Management and Analysis

Correlation analysis was used to establish the relationship between the density of *U. dioica* and species richness, diversity, and density of other herbaceous species. One-way ANOVA was used to determine the significant differences in the mean concentration of nitrogen and phosphorous with the density of *U. dioica* and other herbaceous species in different land-use types. Qualitative data from the assessment of the market presence of raw and value-added *U. dioica* products together with local knowledge on the uses of *U. dioica* in local communities were analyzed using International Business Machine Statistical Package for Social Sciences (IBMSPSS) version 20.

CHAPTER FOUR

RESULTS

4.1 Herbaceous species composition

There were twenty-five herbaceous plant species identified in the study area from 13 different families (Figure 4.1). The Family *Asteraceae* had the highest number of species (7) (Table 5.1) followed by *Amaranthaceae* (4), *Solanaceae* (3), and *Rubiaceae* with 2 species. Families *Urticaceae, Portulacaceae, Oxalidaceae*, and *Euphorbiaceae* had one species each (Table 5.1). The presence of *Spillanthes mauritiana (Asteraceae)* was found to be predominant in addition to *Urtica dioica* (*Urticaceae*) whose presence was frequent in all land use types studied (Figure4.1)

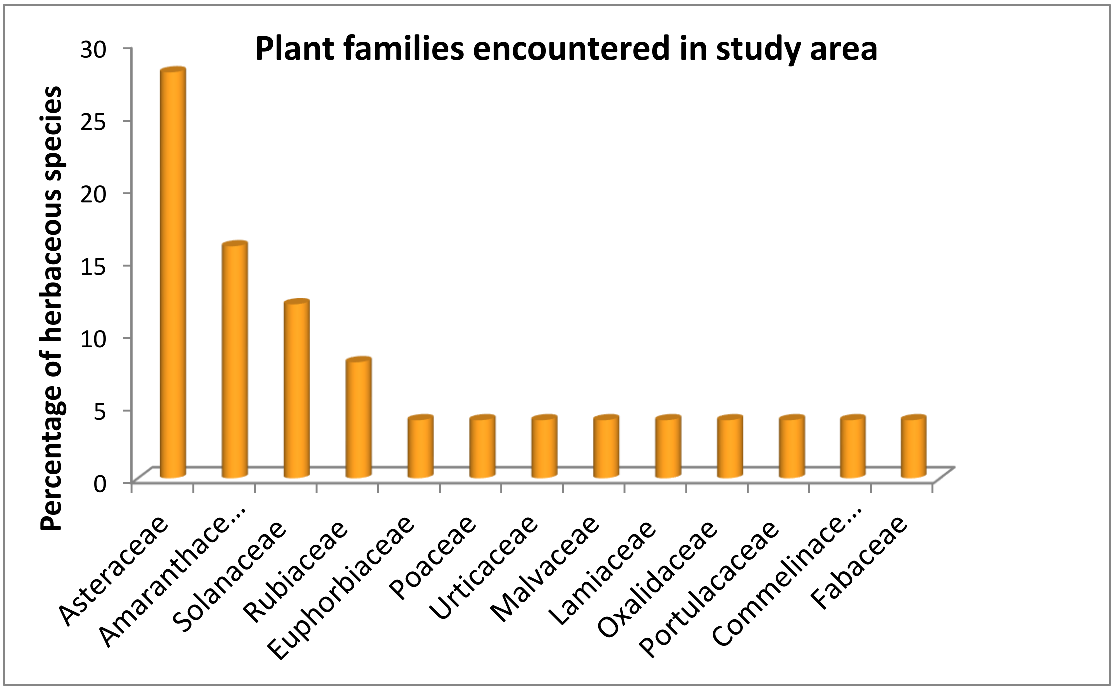


Figure 4.1: Plant families encountered in the study area

4.2 Effects of *U. dioica* density on other species diversity, density, and species richness.

Urtica dioica density was found to be widely dominant among the five land-use types; roadside, residential, pastureland, cropland, and riverbank areas. Across the study area comparative analysis of means density of *U. dioica* revealed a significant statistical difference (p < 0.05) with highest densities recorded on riverbanks in Charity and Watuka with mean densities of 207±6.78^{a} and 206±6.90^{a}, correspondingly (Table 4.1). The least density (31±0.84^{c}) was recorded in the cropland area in Endarasha (Table 4.1).

Table 4.1: Mean density of *U. dioica* across the study area

Sites	**The density of *Urtica dioica* /m^2 (Mean±SE Mean)**				
	Roadside	**Residential**	**Pastureland**	**Cropland**	**Riverbank**
Endarasha	98±6.21^{a}	91±2.25^{b}	90±2.48^{b}	31±0.84^{c}	56±3.58^{c}
Charity	94±3.12^{b}	77±2.30^{b}	73±2.23^{c}	47±0.58^{c}	207±6.78^{a}
Watuka	140±4.68^{a}	103±1.52^{a}	72±2.38^{c}	54±0.67^{c}	206±6.90^{a}

Mean values followed with different superscript letters within the same column are significantly different at p < 0.05 by Tukey's post hoc test.

4.2.1: Effects of *U. dioica* density on species diversity.

From the Shannon Wiener diversity index, the diversities of plant species in different land-use types were obtained. The highest diversity index was recorded in cropland **(**1.61±0.04^{c}) with the lowest from pastureland (0.34±0.01^{a}). The diversity values ranged from $0.34 \le H \le 1.61$. (Table 4.2). The results from Pearson correlation analysis depicted that, there was a strong negative correlation between the density of *U. dioica* and herbaceous species diversity (r = -0.8). Sites that had a low density of *U. dioica* (31±0.84[c]) had a higher diversity of plant species (1.61±0.04[c] (table 4.2).

Table 4.2: Diversity of plants across the study sites

Sites	**The diversity of plant species /m²** **(Mean±SE Mean)**				
	Roadside	**Residential**	**Pastureland**	**Cropland**	**Riverbank**
Endarasha	0.91±0.03[a]	0.90±0.04[a]	0.34±0.01[a]	1.61±0.04[c]	1.37±0.03[c]
Charity	0.69±0.04[a]	0.54±0.02[b]	1.55±0.03[c]	1.21±0.04[b]	0.61±0.11[a]
Watuka	0.40±0.02[b]	0.62±0.00[a]	1.19±0.03[b]	1.40±0.03[c]	0.75±0.01[a]

Mean values followed with different superscript letters within the same column are significantly different at $p < 0.05$ by Tukey's post hoc test.

4.2.2 Effects of *U. dioica* density on species richness.

From Pearson correlation analysis, means density of *U. dioica* and herbaceous species richness were significantly different, with a negative correlation coefficient (r = -0.2, $p < 0.05$). Apart from croplands, sites that had high density of *U. dioica* had less herbaceous plant species richness.

4.2.3 Effects of *U. dioica* density on other species density

Out of the 25 plant species, encountered alongside *U. dioica* (table 5.1) four species namely *Spillanthes mauritiana*, *Portulaca oleracea*, *Ricinus communis*, and *Abutilon grandiflorum* were selected for correlation analysis since their presence was encountered frequently. Results showed a negative correlation coefficient between the densities of *U. dioica* and other herbaceous plant species. Their mean density was found to be statistically different at $p<0.05$ from that of *U. dioica*. Increase in *U. dioica* density led to a decrease in the number of *Spillanthes mauritiana*, (r = -0.9, $p < 0.05$), *Portulaca* *oleracea*, (r = -0.1, $p < 0.05$) *Ricinus communis (r=-0.7,* $p < 0.05$*)*, and *Abutilon grandiflorum* (r= -1, $p < 0.05$).

Among the four herbaceous species chosen for statistical correlation analysis, it was observed that *Spillanthes mauritiana* species had synergy occurrence along with *U. dioica* persisting despite *U. dioica* dominance, particularly along roadside, cropland, and riverbank.

4.3 Determination of the effects of abundance of *U. dioica* in relation to the mineral content of soils in Kieni West Sub County, Kenya

The analysis of variance in concentration of nitrogen and phosphorous in different land types showed significant statistical difference in the mean concentration of nitrogen (F=4.8495, df=4, 14, $p < 0.05$) and phosphorous (F=4.3589, df=4, 14, $p < 0.05$) among different land types. Mean nitrogen concentration was notably higher in riverbank (37.94±0.81 mgNL^{-}) as compared to the phosphorous concentration (8.57±0.57 mgPL^{-}) in the same land use type (Table 4.3). There was also a strong positive correlation (r= +0.8482) between nitrogen and phosphorous concentration with the density of *U. dioica* in different land types.

Table 4.3: Minerals content of the soil in Kieni West Sub County, Kenya

Sites		**The mean concentration of Nitrogen and Phosphorous in soil samples** (mgL^{-}) **(Mean±SE Mean)**				
		Roadside	**Residential**	**Pastureland**	**Cropland**	**Riverbank**
Endarasha	N	29.67±2.26^{a}	23.09±2.40^{a}	32.44±3.14^{a}	24.97±2.52^{a}	1.17±0.13^{d}
	P	9.62±1.17^{b}	10.05±2.24^{b}	6.30±1.83^{b}	2.75±0.59^{c}	4.52±0.42^{c}
Charity	N	1.70±1.93^{c}	0.23±0.03^{d}	1.33±0.87^{d}	0.16±0.03^{d}	27.48±1.09^{a}
	P	8.98±1.57^{b}	2.65±0.52^{c}	9.82±2.06^{b}	2.51±0.7^{c}	8.26±1.60^{b}

Watuka	N	19.38 ± 0.84^a	17.31 ± 1.25^a	22 ± 2.61^a	16.39 ± 1.81^a	37.94 ± 0.81^a
	P	6.44 ± 1.28^b	5.87 ± 0.53^b	5.38 ± 0.74^b	5.67 ± 0.64^b	8.57 ± 0.57^b

Mean values followed with different superscript letters within the same column are significantly different at $p < 0.05$ by one-way ANOVA and Tukey's post hoc test.

4.4: Assessment of the market presence of raw and value-added *U. dioica* products

Table 4.4 shows results of *U. dioica* products encountered and its incorporated products in the local markets of Nyeri County including Nyeri town. There was significant statistical difference ($p < 0.05$) in the market price of raw and value-added *U. dioica* products. From various *U. dioica* products market prices, it was noted that value-added products had higher local market prices as compared to the raw form of *U. dioica.*

Table 4.4: Local markets value-added *U. dioica* products and its incorporated products.

Value-added *Urtica dioica* product	Quantity	Local price (Ksh)	Use
Porridge flour	1kg	100	Porridge
Urtica dioica powder	500g	250	Food additive
Urtica dioica Ugali flour	1kg	100	Food
Herbal tea leaves	100g	190	Herbal tea
Urtica dioica fresh leaves	1 bundle	20	Vegetable

Some of locally available value-added *U. dioica* products in Nyeri county markets are shown in figure 4.2 below.

A)Value added *Urtica dioica* in porridge flour

B) Fresh *Urtica dioica* Vegetable

C)Locally value-added *Urtica dioica* flour

D) Value added *Urtica dioica* food additive

E) Value added *Urtica dioica* herbal tea

F) Value added *Urtica dioica* powder

Figure 4.2: Products from value-added and fresh *Urtica dioica*.

Results from the assessment of the differences in the forms of *U. dioica* sold in Nyeri county local markets is summarized in the table 4.5 below.

Table 4.5: Assessment of differences in the form of *U. dioica* sold by the respondents

Form of *U. dioica* products sold by respondents	Frequency N=156	Percentage %
Value added product form	87	56
Both fresh and value added form	39	25
Fresh *U. dioica*	30	19
Total	156	100

Figure 4.3 indicates differences in the form of *U. dioica* sold by the respondents. From the interviews, 56% of the respondents reported preferring selling *U. dioica* when value-added. 25% of the sellers of *U. dioca* were focused on selling both fresh and value-added products while only 19% of the respondents were selling fresh forms of *U. dioica*.

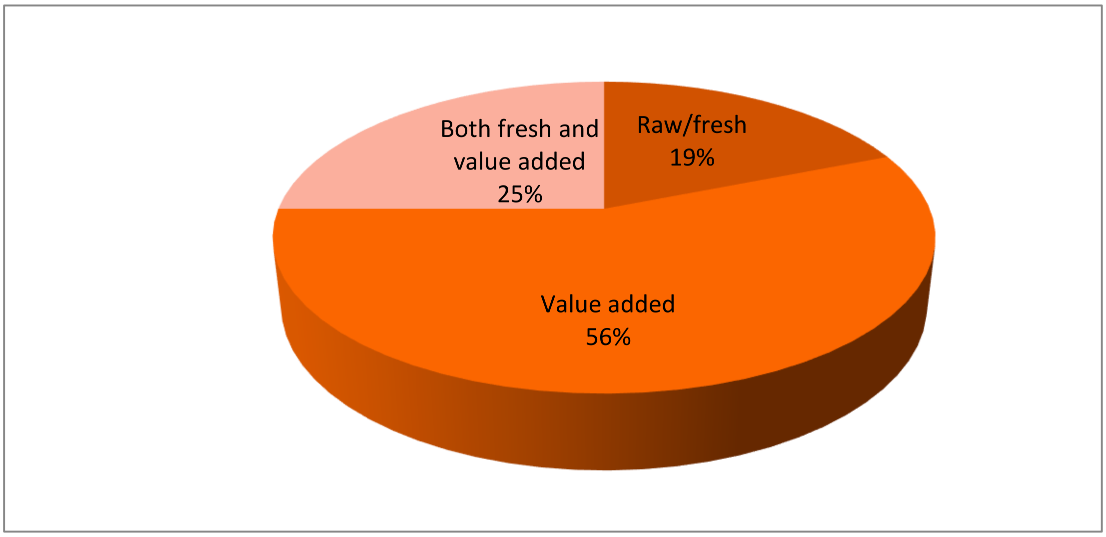


Figure 4.3: Sellers of *U. dioica* farm products

The study revealed that 58% of the sellers obtain their *U. dioica* products from middlemen, with 35% sourcing the product from companies while only 7% obtain the product from farmers.

4.5: Local knowledge on the uses of *U. dioica* in local communities.

4.5.1: Use of *Urtica dioica* for medicinal purposes

All the respondents (100%) reported having used *U. dioica* for medicinal purposes. It was noted that water from boiled leaves is locally used to manage arthritis and treat diabetes in human beings. Boiled water from leaves and roots is given to a cow that has recently calved as an alternative source of minerals such as calcium to give it strength to stand upright.

4.5.2: Preparation methods

All the respondents (100%) indicated that they used decoction and infusion as methods of locally extracting medicinal value from *U. dioica* roots, leaves, and stems. Products obtained from leaves were found to be used locally as herbal tea; products from roots, leaves, and stems are consumed for the management of diabetes, dried leaves were noted to be given to laying chicken to induce the yellowing of egg yolk aimed at improving their quality and enhancing their marketability.

Figure 4.4 shows the level of the usefulness of *U. dioica*. From the study, it was determined that 50% of the respondents reported using *U. dioica* as human food mainly as vegetables and food additives, and 33% of the respondents noted that the use of *U. dioica* as medicine is very useful mainly in the management of diabetes, 14% of the respondents noted that dried leaves of *U. dioica* are useful when used as cattle feeds especially during droughts to compensate for reduced animal fodder while only 3% of the respondents considered use of *U. dioica* as chicken feeds aimed at increasing nutritional quality of eggs to be very useful (Fig 4.4).

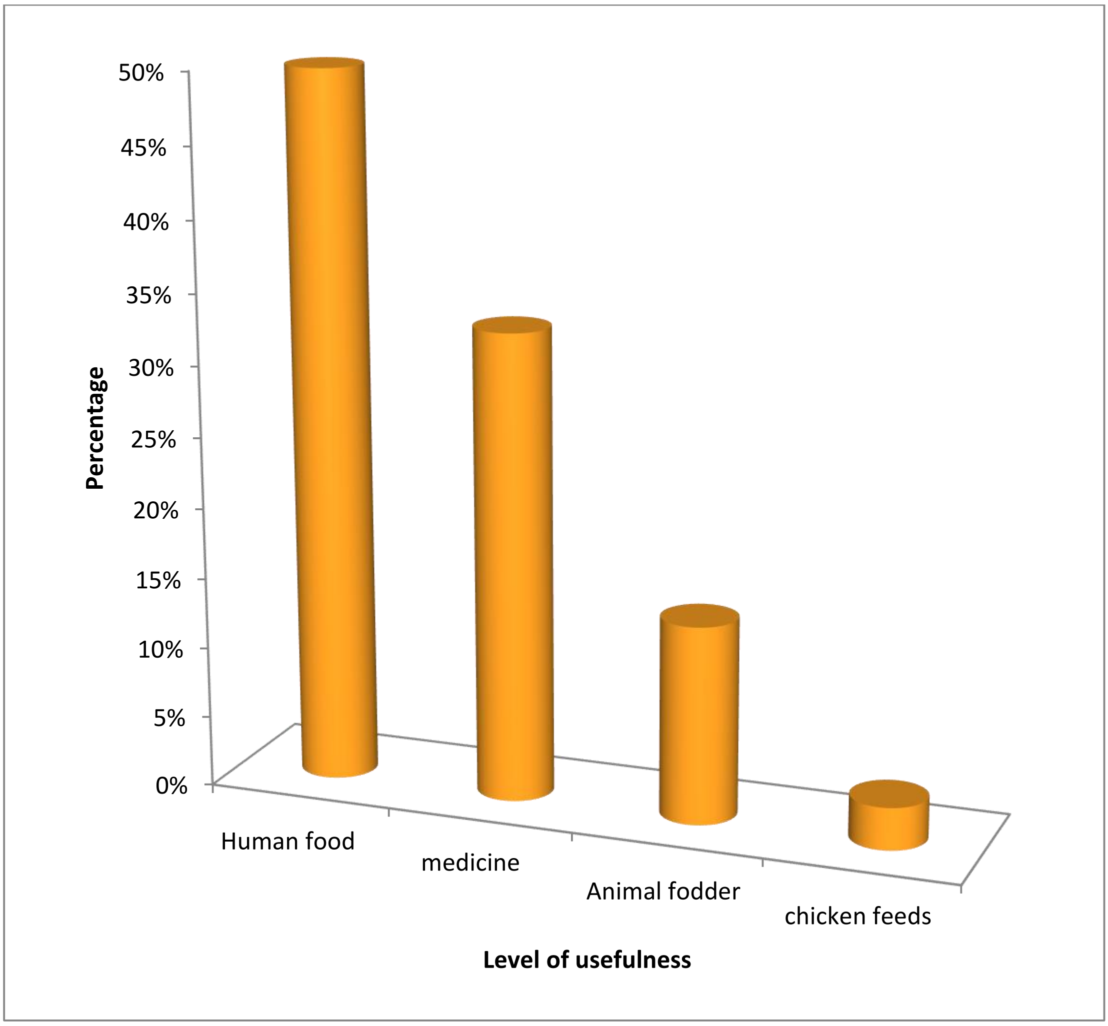


Figure 4.4: Level of the usefulness of *U. dioica*

4.5.3: General trend on the abundance of *U. dioica* in the study area in the past ten years.

From the study, 67% of all the respondents indicated that there has been an increasing trend in the level of invasiveness of *U. dioica* while only 33% reported a decreasing trend in the level of invasiveness of *U. dioica* in the study area (Figure 4.5**)**. Resistance to weather changes and its invasive nature were the reasons for its increasing trends while increased cultivation and construction due to increased settlement were cited as the reasons for the reduced abundance of *U. dioica*.

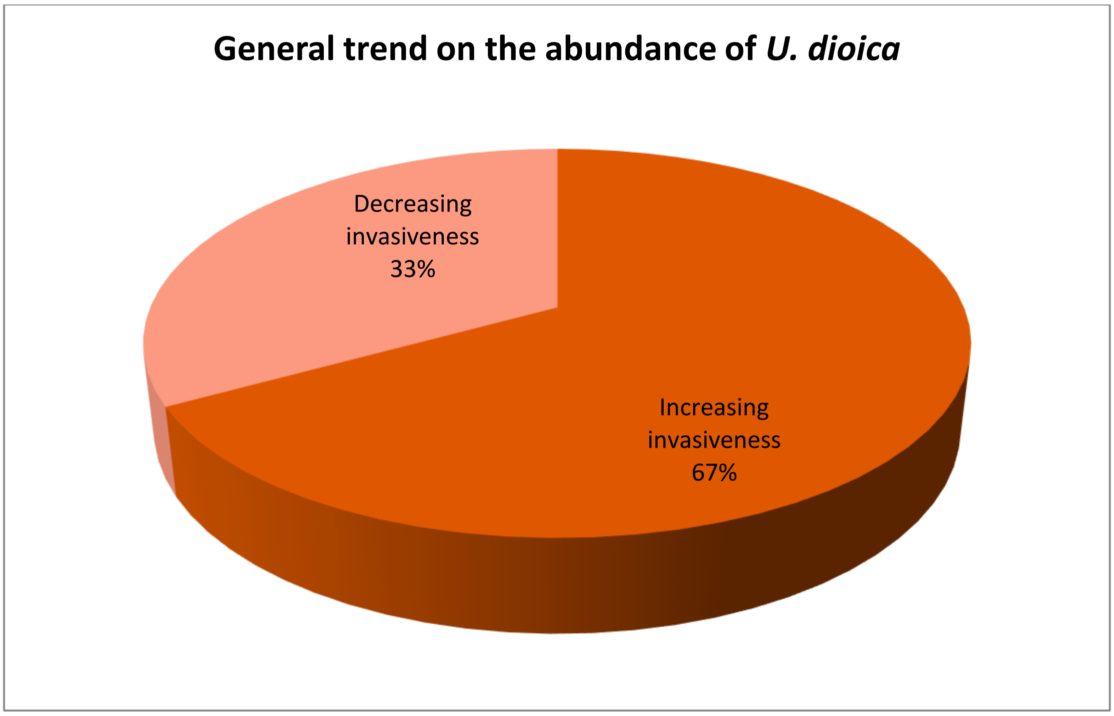


Figure 4.5: General trend on the abundance of *U. dioica*

4.5.4: Consumption of *U. dioica* in comparison to other vegetables

The study found that 100% of the respondents rate *U. dioica* as among the most consumed vegetable in the study area because it is readily available in its natural habitats. Furthermore, it was noted that the plant products are readily available in the local markets.

4.5.5: Source of *U. dioica* by local communities

The results indicated that 61% of the respondents obtain *U. dioica* from the nearby Aberdare Forest. While 39% had set aside an area within their farms to grow *U. dioica.*

4.5.6: Use of *U. dioca* as a medicinal plant for primary health care

Results analysis of the local knowledge on the use of *U. dioica* as a medicinal plant across age and gender is presented in Table 4.6.

Table 4.6: Use of *U. dioica* as a medicinal plant for primary health care across gender

Use of *U. dioca* as a medicinal plant for primary health care across gender	
Chi square test	44.43
DF	4
N	198
CI	95%

A chi-square test of independence was performed to assess the relationship between age and gender in the use of *U. dioica* as a medicinal plant for primary health care. There was statistical significant relationship between age and gender in the use of *U. dioica* X^2 (4, N =196) =44.43, $p < 0.05$. From the analysis results, women aged sixty years and above were more likely to prefer use of *U. dioica* as a medicinal plant in comparison to men.

CHAPTER FIVE

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

5.1 DISCUSSION

5.1.1: Effects of *U. dioica* density on other species diversity, density, and species richness.

The current study has found that an increase in the abundance of *U. dioica* was inversely proportional to the density, diversity, and species richness of other herbaceous plants. Areas with a high density of *U. dioica* recorded reduced density, diversity, and species richness of other herbaceous plant species. This can be attributed to their better establishment, aided by their reproductive potential and root propagation adaptability, as compared to other native herbaceous species. According to Bayer CropScience (2015), *U. dioica* has been recorded among the weeds with diverse establishments, ranging from pasturelands, roadsides, and floodplains, and highly favored by fertile soils. Because of its competitive advantage in nutrient absorption, it is also highly adaptable to establishing itself across a wide range of land-use types. The impacts of plant invasion on species diversity were found to be consistent with a study conducted in southern Ethiopia, in which colonization by invasive species *Parthenium hysterophorus* L. weed led to a decrease in the diversity and abundance of all other herbaceous species (Ayele *et al*., 2013). Similarly, a study by Pyšek *et al*. (2012), found that interaction between invading species has reduced the abundance of native plant species.

Among the four herbaceous species chosen for statistical correlation analysis, that is, *S. mauritiana*, *P. oleracea*, *R. communis,* and *A. grandiflorum,* it was found that their density decreased with an increase in the density of *U. dioica.* Despite the dominance of *U. dioica,* the occurrence of these species was noted in almost all the study sites. For instance, Uddin *et al.* (2014) noted that *Portulaca oleracea* is widely distributed due to its competitive advantage over other species for the utilization of mineral resources, owing to its deep-rooted adaptability and high prolificacy. Globally, *A. grandifolium* is also considered to be potentially invasive in the Pacific Islands (Meyer, 2014), it was therefore found to compete relatively with *U. dioica*. It was observed that *S. mauritiana* had synergy occurrence along with *U. dioica,* persisting despite *U. dioica* dominance, particularly along roadside, cropland, and riverbank. This may be attributed to similar edaphic mineral requirements between *U. dioica* and *S. mauritiana*.

The high density of *U. dioica* along the riverbanks, mainly due to plenty of water was found to reduce the species richness of other herbaceous plants to a greater extent. For instance, the species richness of *Galium aparine,* which is useful in blood purification as noted by Ilina *et al.*, (2019) and often associated with *U. dioica* (Jabłońska-Czapla *et al*., 2020), was greatly reduced, often missing in plots with a high density of *U. dioica.*

It was also evident that the density of *U. dioica* in riverbanks remained relatively higher when compared to other land-use types. The formation of dense shading by the *U. dioica* leaves and network of rhizomes in the soil can be attributed to the reduced growth of other herbaceous species. Results of this study were consistent with the study conducted in America (Califonia) by Perry, (2010), which found density to be highest in wildlands, mainly in areas surrounding streams or rivers.

5.1.2: Determination of the effects of abundance of *U. dioica* in relation to the mineral content of the soil in Kieni West Sub County, Kenya

In comparison with a phosphorous concentration in the soil, research findings indicated that a higher concentration of nitrogen in the soil has a greater impact on the invasive nature of *U. dioica*. It was also noted that with a higher concentration of both phosphorous and nitrogen, there was a corresponding increase in the density of *U. dioica.* This indicated that the concentration of nitrogen and phosphorous was directly proportional to the density of *U. dioica.* This was found to concur with Viktorova *et al.* (2016), that *U. dioica* has a high potential to absorb minerals content from the soil. Vegetative growth of *U. dioica* has been noted to be greatly influenced by the high concentration of nitrogen in the soil (Taylor, 2009). Pasturelands were found to have a high concentration of both nitrogen and phosphorous in comparison to other land types. This was found to be consistent with a study in America by Elliott, (1986) that, in contrast to nitrogen, the atmosphere does not provide phosphorus to the soil thus, unlike phosphorous, some of the nitrogen is naturally added from the atmosphere through Nitrogen fixation. It has been reported that large herbivore grazing has a positive correlation with the level of nitrogen in the soil (Liu *et al*., 2016). The higher density of *U. dioica* in pasturelands may be associated with the high concentration of nitrogen and phosphorous in these land types. This may be attributed to organic manure released by grazing animals. It has also been reported that grazing cattle can distribute nutrients in the soil, especially in areas where intense grazing occurs (Masters *et al*., 2007). Though the concentration of nitrogen and phosphorous was found to be relatively higher in croplands, weed management by farmers in croplands may have contributed to the reduced density of *U. dioica* in croplands. This was found to agree with findings by Chowdhury *et al.* (2014), that is, weeding in croplands by methods such as the application of herbicides has been found to reduce the establishment of invasive weeds hence significantly reducing their density.

5.1.3: Assessment of the market presence of raw and value-added *U. dioica* products

The study findings were that the highest number of retailers concentrate more on value-added product forms of *U. dioca,* followed by retailers who sell both raw and value-added forms of *U. dioica*. The least number of retailers were found to concentrate only on selling raw forms of *U. dioica*. The high number of individuals selling value-added forms of *U. dioica* can be attributed to the diverse uses of these products as noted by Munene, (2020).

It was noted that locally valued-added products of *U. dioica* range mainly from food to medicinal products. This has subsequently created job opportunities for many members of the community in which the plant grows. The invasive nature of *U. dioica* combined with its ability to grow in diverse habitats has made it easily accessible for market purposes as noted by Tarus *et al.* (2019)

5.1.4 Local knowledge of the uses of *U. dioica* in local communities.

From the study, it was noted that major consumption of *U. dioica* products ranges from food to medicine. This was found to agree with Jan *et al*. (2017) who reported that one of the distinguishing reasons for the high consumption of *U. dioica* as food is its widespread in many countries, especially in the Mediterranean region, and its high digestibility together with high mineral contents of *U. dioca* leaves.

The study also found that there has been a general increasing trend of *U. dioica* invasiveness over the last 10 years. It was noted that despite weather changes in the region leading to decreased annual precipitation *U. dioica* has been resistant to low rainfall patterns (Ochieng *et al*., 2016). This was attributed to its resistance to weather changes, in addition to its good adaptation for dispersal. This was found to concur with

Perry, (2010) who noted that *U. dioica* has a dense rhizome that ensures its survival while enduring adverse weather changes throughout the year.

All respondents in the study reported that they have used *U. dioica* as a vegetable which was found to be in consent with the study by Rutto, (2013) who noted high consumption of *U. dioica* in Nyeri county, primarily as a fresh vegetable whereby it is added to soups, cooked as a potherb, or used as a vegetable complement in dishes.

The study found the invasive nature of *U. dioica* as the main reason for the failure of farmers to cultivate the plant on their farms. It was also noted that farmers who had attempted to cultivate the plant for commercial and domestic consumption later found it difficult to control it due to its fast dispersion rate and its ability to suppress other food crops. The majority of members of the community, therefore, are noted to rely on naturally growing *U. dioica* in the Aberdare Forest and on their farms where it grows as a weed. This was in agreement with Mutiso, (2019) who noted that members of the community extract stinging nettle for domestic and commercial purposes from the forest. The study established that women have a high preference for using *U. dioica* for medicinal purposes as compared to men in the same community. This was found to concur with the study conducted in Nigeria by Adebo *et al*. (2011) who noted that women had more experience in the use of herbal medicinal plants. Roots, leaves, and stems were noted as the parts that have medicinal value in *U. dioica*. Locally water boiled from the leaves of *U. dioica* is used to treat arthritis and diabetes in human beings. This was found to agree with Bisrat *et al*. (2016) who found *U. dioica* to be an alternative drug by local communities for diabetes.

Decoctions from roots, leaves, and stems are used locally to boost blood levels in human beings. Through infusion, it was noted that *U. dioica* is used as herbal tea by soaking leaves of *U. dioica* in boiled water and allowing it to cool. This corresponded with the study by Tarus *et al*. (2019) who found high administration of nettle products such as nettle herbal tea compared to nettle soup. Locally water from boiled roots and leaves is given to cows that lack the strength to stand upright after calving to act as an alternative source of minerals such as calcium. This was found to be consistent with the study by Rafajlovska *et al.* (2013), which found *U. dioica* to be rich in minerals and trace elements including calcium, manganese, copper, magnesium, and zinc. Appendix 3 summarizes some of the economic importance of other herbaceous plant species encountered in the study area.

5.2 Conclusions

- The study established that the highest densities of *U. dioica* were recorded mainly in riverbanks and pastureland; with Watuka study area having the highest densities. It was noted that high densities of *U. dioica* in riverbanks pose a threat to biodiversity due to decreased diversity, richness, and density of other herbaceous flora.
- From the study, it is evident that species richness of *G. aparine* often associated with *U. dioica* was greatly reduced often missing in plots with a high density of *U. dioica.*
- Invasion of *U. dioica* in pasturelands leads to a reduction in pastures which consequently have negatively impacted the quantity of milk and meat produced by cattle.
- The study established that *S. mauritiana* species had synergy with *U. dioica* and it was found to persist despite *U. dioica* dominance, particularly along roadside, cropland, and riverbank.

- The study established that soils in Watuka and Charity support the growth of *U. dioica* more than in Endarasha. The high concentration of nitrogen in Watuka was found to correspond to high densities of *U. dioica*. It is also apparent that a high density of *U. dioica* in a habitat can be used as a prerequisite indicator for high contents of nitrogen and phosphorous minerals in the soil.
- There is higher consumption of value-added forms of *U. dioica* as compared to fresh *U. dioica.*
- Locally, members from Endarasha, Charity, and Watuka suffering from arthritis, blood pressure, and diabetes confirmed to self-medicate themselves using extracts from *U. dioica.*
- During drought, water from boiled leaves and roots is given to a cow that has recently calved and lacks the strength to stand upright to act as an alternative source of minerals such as calcium in livestock farming.
- Laying chicken are fed with dried *U. dioica* powder to induce the yellowing of egg yolk aimed at enhancing their marketability locally.
- Due to the stinging nature of *U. dioica*, cultivation of the plant has not been embraced.
- The study established that control of *U. dioica* spread by farmers through weeding and the use of herbicides in the agricultural sector have increased the cost of production.

5.3: Recommendations

- Further studies should be carried out to analyze the active phytochemicals in various tissues of *U. dioica* to help formulate effective processing of high-quality products.

- There is a need to address the invasiveness of *U. dioica* in pastureland through increased harvesting of the plant for processing purposes to ensure quality forage for free grazing cattle.
- Increasing public awareness of the benefits of *U. dioica* to boost its consumption hence reducing its invasiveness through health campaigns.
- The national and county governments to encourage innovation in the processing of *U. dioica.*

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APPENDICES

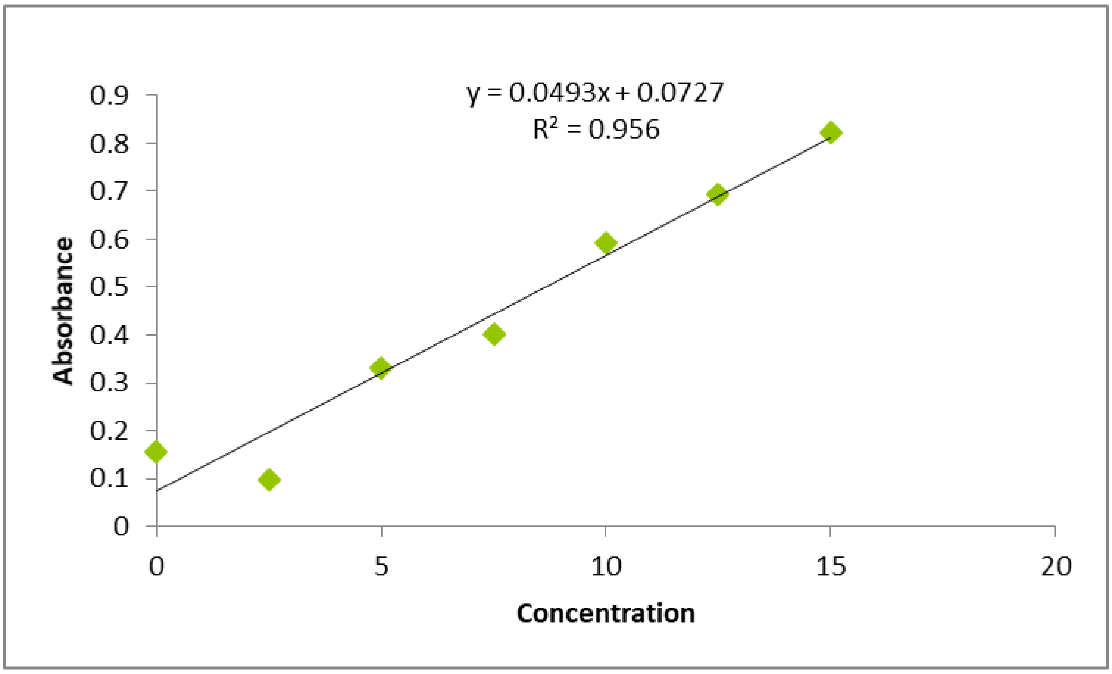
Appendix 1: Summary of knowledge gaps from published papers

YEAR	AUTHOR	RESEARCH DONE	FINDINGS	KNOWLEDGE GAP
2019	Tarus *et al*	Medicinal and Dietary Value Of Stinging Nettle To Rural And Urban People Within Aberdare And Mt Kenya Forest Landscapes	52.9% use stinging nettle to treat diabetes as an local medicinal herb, with over 25% using the plant to treat high blood pressure, Arthritis, Rheumatism, and Allergies.	Further research on the uses of *U. dioica,* including possible large-scale exploitation of the herb for medical and food supplement purposes in Kenya
2009	Taylor	Biological Flora of the British Isles	On very fertile soils, *U. dioica* develops into a thick canopy during the initial stages which prevent other herbaceous plants from accessing maximum sunlight	Factors that check the growth of *Urtica dioica*

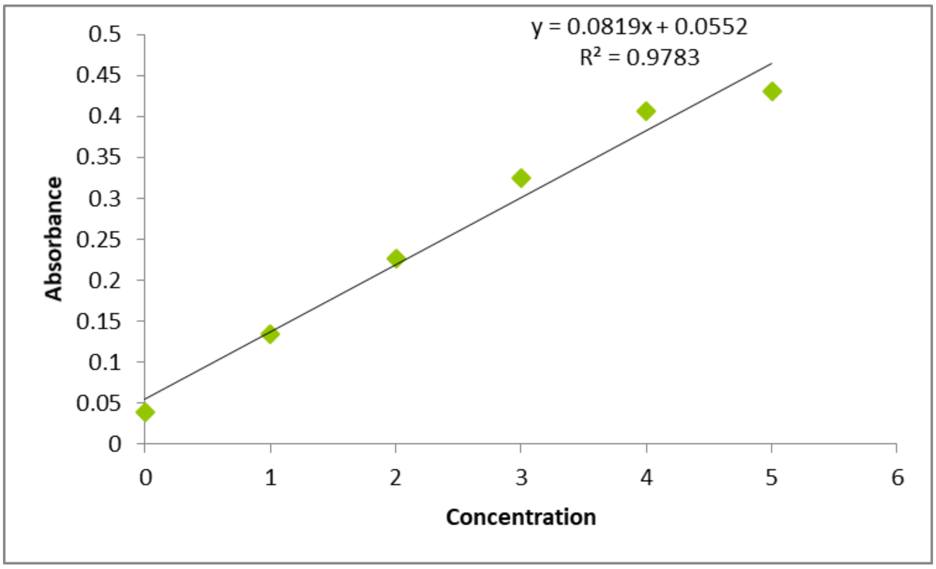
2015	Lockton *et al*	*Urtica dioica* and *U. ga leopsifolia.*	The invasive nature of *U. dioica* is due to high seed production, which establishes itself in areas previously occupied by other invasive weeds. Consequently, this reduces species diversity and subsequent formation of pure stands of *U. dioica;*	Role of *U. dioica* to Biodiversity

Appendix 2: Calibration curves

Calibration curve of Nitrogen



Calibration curve of Phosphorous



Appendix 3: Economic importance of herbaceous species found in the study area

NAME OF SPECIES	COMMON NAME	FAMILY	ECONOMIC IMPORTANCE
Sonchus oleraceus	Sow thistle/ milk thistle	Asteraceae	The leaves of *S. oleraceus* have been consumed mainly as salad greens. It is similarly cooked like spinach. Tanaka, *et al*., (2007).
Achyranthea aspera	prickly chaff flower	Amaranthaceae	The flowering spikes rubbed with a little sugar, are made into pills, and given internally to people bitten by mad dogs. List *et al*., (2007)
Spillanthes mauritiana	Toothache plant	Asteraceae	used as herbal tea to cure anxiety, stomach disorders, and toothache Paulraj, *et al*., (2013).
Anthemis cotula	Mayweed	Asteraceae	Traditionally *A.cotula* has been used as traditional herbal medicine to induce menstruation and in the treatment of uterine membrane.

			Sut, S *et al*., (2019) Adhikari *et al*., (2020).
Cyathula orthacantha	*Cyathula*	Amaranthaceae	Concoctions obtained from crushing and dissolving roots of *C. orthacantha* are consumed in the treatment of stomach-ache Bernard *et al*., (2015).
Erigeron Canadensis	Butterweed	Asteraceae	Locally *E. Canadensis* leaves have been used in America during the preparation of herbal medicine to cure sore throat in addition to dysentery Wu, B. Zhang *et al*., (2019).
Urtica dioica	stinging nettle	Urticaceae	The leaves of *U. dioica* are dried and may then be used in the preparation of herbal tea. Fresh leaves have also been prepared and consumed as vegetables. Kregiel *et al*., 2018

Abutilon grandiflorum	flowering maple	Malvaceae	*A. grandiflorum* has been grown as a potted plant to act as an ornamental plant in homes and offices. Quattrocchi, (2012).
Cyathula polycephala	Cyathula	Amaranthaceae	Leaves and roots of *C. polycephala* are locally used in the preparation of herbal medicine for treatment of stomach-ache Kareru *et al*., (2007).
Crassocephalum picridifolium	Ragleaf	Asteraceae	*C. picridifolium* has been confirmed to have anti-diabetic properties. Agize, *et al.*, (2013).
Conostomium guadrangulare	Conostomium	Rubiaceae	Source of nectar for pollination. Williams, J. H. (2012).
Portulaca oleracea	little hogweed	Portulacaceae	The stems, leaves, and flower buds are all edible raw, or cooked Okafor *et al*., (2014).

Amaranthus hybridus	Pigweed	Amaranthaceae	*A. hybridus* leaves have been used as a vegetable. Akubugwo, *et al.,* (2007).
Commelina benghalensis	wandering Jew	Commelinaceae	In Pakistan, *C. benghalensis* leaves have been used in the preparation of animal fodder Lanyasunya *et al*., (2008).
Galium aparine	Stickywilly/ goosegrass	Rubiaceae	*G. aparine* has been reported to have blood antioxidant properties. Ilina *et al.,* (2019).
Leonotis Africana	lion's tail	Lamiaceae	*L. Africana* has been reported to cause mild euphoria, visual changes, dizziness, nausea, sweating, sedation, and Lightheadedness. Pushpan *et al*., (2012).
Solanum tuberosum	Potato	Solanaceae	Used to make animal feeds. Khalid *et al*., (2020).

Pisum sativum	Pea	Fabaceae	Seeds from *P. sativum* have been used in the preparation of vegetables. Dahl *et al*., (2012).
Physalis angulate	angular winter	Solanaceae	*P. angulate* is often consumed by humans when raw or cooked. Silva, *et al.*, (2005).
Bidens pilosa	Blackjack	Asteraceae	*B. pilosa* has been recorded as an invasive herbaceous weed. It has been noted as a problematic weed to food crops in over forty countries. Bartolome *et al.*, (2013).
Tagetes minuta	stinking Roger	Asteraceae	Used in the manufacture of oil. Cornelius *et al*., (2016).
Solanum incanum	thorn apple	Solanaceae	Roots from *S. incanum* have been used as traditional herbal medicine in the treatment of stomach and toothache. Sbhatu, *et al.*, (2020).

Ricinus communis	castor oil plant	Euphorbiaceae	Seeds of *R. communis* have been confirmed to have medicinal properties in the management of diseases such as bilharzia, arthritis, abdominal disorders, backache, muscle aches, and prolonged backache Gómez, *et al.*, (2016).
Oxalis latifilia	*Oxalis*	Oxalidaceae	*O. latifilia* has been used in the preparation of herbal medicine for the treatment of infections along the urinary tract, diarrhea, and poisonous snake bites. Anand, *et al*., 2013.
Zea mays	Maize	Poaceae	*Z. mays* has been used as a food and preparation of livestock feeds. Wolf *et al*., (2009).

Appendix 4: Diversity, density, and species richness of all individual species

Data Sheet 1: Density of *U. dioica* and other herbaceous species in all quadrats

Name of observer…………………………………………………………Date………

Beginning GPS lat; ……………..N Long; ………………………………..............

End GPS lat………………………N Long; ………………………………….........

Weather condition: cloudy/clear sky/rain………………………………………..

Description of the study area (e.g. wetland, dry land e.tc.) …………….…………..

Description of sample plot (e.g. standing water, shady e.t.c.)

……………………………………………………………………………………….

Plot ID number/label…………………………………………………………………

Name of species	**Number of individuals in different quadrats each of 1 square meter size**					**Total number of individuals**	**Density**
	1	2	3	4	5		
A.							
B.							
C.							
D.							
E.							
F.							
G.							
H.							

Appendix 5: Minerals content of the soil in Kieni West Sub County, Kenya

Datasheet 2: Soil samples

Name of observer……………………………………………………………Date………

Beginning GPS lat; ……………..N   Long; ………………………………..............

End GPS lat………………………N   Long; ………………………………….........

Weather condition: cloudy/clear sky/rain………………………………………..

Description of the study area (e.g. wetland, dry land e.tc.) …………….…………..

Description of sample plot (e.g. standing water, shady e.t.c.) ……………………….

Plot ID number/label………………………………………………………………….

Sites		**Soil samples**				
	Plot No	**Riverbank**	**Residential**	**Cropland**	**Pastureland**	**Roadside**
Endarasha						
Charity						
Watuka						

The interview guide will consist of questions focusing on; presence in the market, and both existing developing value addition forms of the herb.

Appendix 6: Interview guide on the market presence of raw and value-added *U. dioica* products

Interview no. __________

INTRODUCTION

I am a Masters student in Plant Ecology at Kenyatta University. As part of my study, I am researching the market presence of raw and value-added *U. dioica* (stinging nettle) products in Nyeri County. You are kindly invited to participate in this research by honestly answering the questions below. The information provided will be kept confidential and will be used for this study only. Thank you in advance.

Date: _________________ Location: _________________

SECTION A: BACKGROUND INFORMATION.

Gender: Male /Female …… Category of interviewee…………….

SECTION B: Value addition and processing of *U. dioica*

1. In which form do you sell *U. dioica* farm products?

Raw/fresh Vegetable ☐	Value-added ☐
As a constituent in other products ☐	Any other (specify)

1. Most popular *U. dioica* products preferred by consumers,

a. Rawfresh ☐	b. Value-added ☐	c. ☐
d. As a constituent in other products ☐	e.	

2. From where do you access *U. dioica*

a. Farmers ☐	b. Middlemen ☐	c. ☐
d. companies ☐	e. Retailers ☐	

A. Name of products that contains *U. dioica* as a constituent.

____

3. Who are your target consumers?

a.Individuals ☐	b. Exports ☐	c. ☐
d.Institutions ☐	e. Any other (specify) ☐	

Appendix 7: Survey of local use of *U. dioica* to the community.

Questionnaire no. __________

I am a Masters student in Plant Ecology at Kenyatta University. As part of my study, I am researching local knowledge on the uses of *U. dioica* (stinging nettle) in the local communities in Nyeri County. You are kindly invited to participate in this research by honestly filling out this questionnaire. The information provided will be kept confidential and will be used for the purposes of this study only.

Answer all questions by ticking in the spaces provided. Put other necessary information sought in these spaces provided where applicable. Thank you in advance.

1. Personal details of the respondents

Name: …………………………….. Sex………………..

Age……………Location………………………………

Date:……………………………Land size (ha)…………………

Profession…………………………………..

2. Data about medicinal uses of *Urtica dioica*:

A) what are the primary activities (economic) you engage in within this location?

Pastoralism ☐	Agro-pastoralism ☐
Agriculture ☐	Any other (specify)

B) Do you use *U. dioica* as a medicinal plant for primary health care?

Yes ☐	No ☐

C) If YES, which part of the plant do you use?

Roots ☐	Stem ☐
Leaves ☐	Any other (specify)

D) How is it prepared and consumed?

Roots ☐	Seed/fruits ☐
Leaves ☐	Any other (specify)

E) What mode of treatment do you prefer?

Traditional medicine from herbs ☐	Modern medicine in the health facility ☐

3**. Utilization**

A) Do you exploit it for other uses apart from being medicine?

Yes ☐	No ☐

B) If yes, State the various Utilization in which they are put into.

………………………………………………………………………………………

C) Which of the following categories is the species is useful: (not, 0; moderately, 1; very, 2)

Food		Live fence	
Medicine		Animal fodder	
Chicken feeds		Compost/Manure preparation	

D) How abundant is the plant in the community? (Rare, 0; moderately, 1; very, 2)

Rare ☐	Intermediate ☐	Common ☐

E) What is the general trend that you have noticed over the past ten years in

Availability of the plant within site?

Increasing ☐	Reducing ☐	No Change ☐

F) State causes of the observed trend in this area below.

a.	b.	c.
d.	e.	

G) In which form do you consume the plant?

Raw/fresh ☐	Powder ☐	Any other (specify)

H) How would you rate your consumption of *U. dioica* in comparison to other

vegetables?

Often ☐	Moderate ☐	When sick only ☐
Most ☐	Rare ☐	

4. Source/ cultivation of the plant

A) Where do you harvest this plant? ....

B) How do you cultivate the plant? ....

C) Is it necessary to conserve/maintain *Urtica dioica* in the area?

Yes ☐	No ☐

D) If Yes, in what way? ……………………………………………….

F) Where do you obtain the plant?

Wild ☐	Farm ☐	Buy Local ☐	Import from other areas ☐

E) Any additional comments/observations concerning the existence of the cultivation within the location?

a) ………………………….............……………………………………………

b) …………………………………………………………………………………

c) ………………………………………………………………………………….

d) ……………………………………………………………………………………

e) ……………………………………………………………………………………

5. Abundance

A. Which months of the year is vegetative growth of *U. dioica* abundant (dominant)

B. Is there a relationship between the amount of rainfall available with the invasiveness of *U. dioica?*

Yes ☐	No ☐

C. If yes, when is the growth of *U. dioica* highest?

High rainfall ☐	Low rainfall ☐	None of the above ☐
Moderate rainfall ☐	No rainfall/drought ☐	

C. Which months of the year do *U. dioica* flowering occur?

D. Which months of the year does the large scale of *U. dioica* harvesting occur?

Datasheet 3: Mean density of *U. dioica* across the study area

Sites	The density of *Urtica dioica* /m^2				
	Riverbank	**Residential**	**Cropland**	**Pastureland**	**Roadside**
Endarasha					
Charity					
Watuka					

$$\boldsymbol{Average\ species\ density} = \frac{(\boldsymbol{density\ in\ plot\ 1}) + (\boldsymbol{density\ in\ \ plot\ 2}) + (\boldsymbol{density\ in\ plot\ })}{\boldsymbol{total\ number\ of\ plots}}$$

Datasheet 4: Diversity of individuals in all quadrats

Species (i)	Number of species in the sample	Pi	ln(pi)	pi ×lnpi
A				
B				
C				
D				

Where i = proportion of total sample represented by species.

Pi= Divide the number of individuals of species I by the total number of samples

NB;

If <1.5, low diversity; 1.5<x<2.5, medium diversity; >2.5, high diversity

Datasheet 5: Mean diversity of plants across the study sites

Sites	The diversity of *plant species* /m^2				
	Riverbank	Residential	Cropland	Pastureland	Roadside
Endarasha					
Charity					
Watuka					

Datasheet 6: Soil analysis

Sites		The soil analysis (Nitrogen in soil sample and phosphorous in soil sample)									
	Plot	Riverbank		Residential		Cropland		Pastureland		Roadside	
		N	P	N	P	N	P	N	P	N	P
Endarasha											
Charity											
Watuka											

Appendix 8: National Commission for Science, Technology and Innovation Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 123273

Date of Issue: 20/November/2021

RESEARCH LICENSE

This is to Certify that Mr.. Joseph Kamicha Wairimu of Kenyatta University, has been licensed to conduct research in Nyeri on the topic: ABUNDANCE AND UTILIZATION OF Urtica dioica L. IN KIENI WEST SUB COUNTY, NYERI COUNTY, KENYA for the period ending : 20/November/2022.

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Appendix 9: Article published from this research work

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Research Article

JOURNAL OF ENVIRONMENTAL SCIENCE AND PUBLIC HEALTH

ISSN: 2575-9612

Indigenous Use and Commercialization of *Urtica dioica* l. from Local Communities of Kieni West Sub County, Nyeri County, Kenya

Joseph Wairimu Kamicha*, Rebecca N. Karanja, and Grace W. Ngaruiya

Abstract

Though the stinging nettle (*Urtica dioica* L.) is categorized globally as an invasive species and nuisance weed due to its stinging trichomes, the plant is a source of vital nutrition and an ingredient in many indigenous medicine practices. *Urtica dioica* has a dense rhizome that ensures its survival, enduring adverse climatic conditions throughout the year. Hence, this study sought to determine indigenous knowledge on the uses of *U. dioica* by the local communities in three parts of semi-arid Kieni Sub County namely Endarasha, Charity, and Watuka. Questionnaires were administered to 196 local informants on the diverse indigenous uses of *U. dioica*. Independent sample t-test showed no significant difference ($P>0.05$) in the use of *U. dioica* as a medicinal plant across gender. 100% of the respondents rated *U. dioica* as among the most consumed vegetable. Thirdly, the study established the use of *U. dioica* in the food, medicine, and veterinary sector. Lastly, despite prolonged adverse climatic conditions in the Kieni region, there has been a general increasing trend of *U. dioica* invasiveness over the last 10 years. Such consumption, coupled with the resistance of *U. dioica* to harsh climatic changes could indicate the future economic potential of the plant species in the local cottage industries to support the government's food production and manufacturing agenda. This study recommends increasing public awareness of the benefits of *U. dioica* to boost its consumption.

Keywords: Indigenous knowledge; abundance; primary health care; biodiversity; invasiveness; Urtica dioica.

Introduction

Stinging nettle (*Urtica dioica* L.), an indigenous perennial species with European origins, is primarily found in moist, fertile, disturbed habitats [1]. This plant is well-known for its stinging hairs, and when touched, it releases toxins like histamine which cause irritational discomfort, therefore cattle will occasionally eat *U. dioica* as a result [2]. As a food item, *U. dioica* leaves possess vitamins, fat, protein, carbohydrates, and minerals, also, besides trace elements, and are therefore used as vegetables and tea in India [3]. *Urtica dioica* is reported to have been used by Europeans and Native Americans for making linens and sailcloth back in the 17th century [4].

In Kenya, *U. dioica* is popular among the Kikuyu and Meru communities, commonly known as "thabai/Hatha" or "thaa," respectively, and is used as a traditional vegetable. Dried leaves are ground into a powder used to make porridge flour [5]. Sometimes it is added to mashed food to enrich it with nutrients [6]. As a way of enhancing food sufficiency, there is, therefore, a

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