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Form Follows Availability: Resource Scan for Sustainable Architecture in Siaya County, Kenya

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Abstract

This study underscores the crucial understanding of local resource availability in circular economy models, particularly within sustainable architecture and civil engineering. The aim is to reduce waste and energy consumption and to diminish reliance on long-distance transportation, thus supporting local economic independence and resilience. Additionally, the study highlights the importance of respecting and integrating cultural heritage within architectural practices. Using a comprehensive mixed-methods approach, including literature reviews, site visits, and interviews with local stakeholders, the research focuses on Siaya County, Kenya. It examines available resources relevant to the architectural practices and climate of the Luo ethnic group. Key findings indicate that the region's soil contains approximately 50% clay, which is essential for developing sustainable earth-building techniques. This local clay resource provides a foundation for environmentally friendly construction methods that reduce dependence on imported materials. In addition, the study identifies *Cassia siamea*, *Eucalyptus spp.*, and *Grevillea robusta* as viable alternatives to the traditionally used *Markhamia lutea* timber. These species not only offer sustainable options but also enhance logistical and economic feasibility due to their local abundance. For thatching, *Cymbopogon* and *Chrysopogon zizanioides* are identified as more durable options compared to *Hyparrhenia hirta*, offering increased longevity and resilience in roofing materials. The study further highlights the potential of natural fibres such as *Agave sisalana* and sugar cane for reinforcing soil bricks, thereby enhancing the structural integrity of earth-based constructions. These findings provide sustainable and durable construction solutions that align with both local practices and resources. This research supports the integration of indigenous materials and culturally respectful architectural practices. It promotes environmentally conscious design solutions that coincide with circular economy principles, fostering cultural and environmental sustainability and promoting the resilience of local communities. By embedding these practices, the study presents a model for developing robust, locally adapted, and culturally sensitive architectural solutions that address current and future challenges in sustainable design.

Keywords: circular economy; economic resilience; harvest map; sustainable building materials; traditional practices; vernacular architecture.

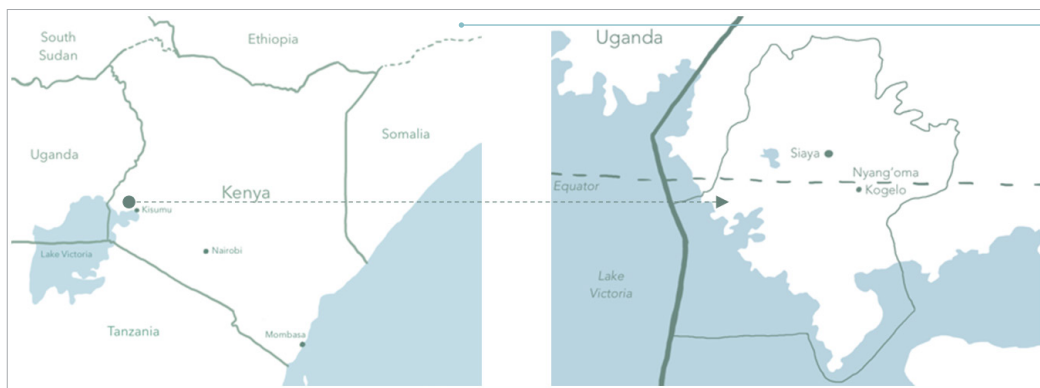


Sustainable construction, an increasingly crucial focus given the construction industry's environmental impact, aims to minimize ecological damage while providing social and economic advantages. It has become a significant area of research and practice as the need to balance development with environmental responsibility grows (Ohiomah et al., 2019). The dominance of "Western" construction techniques in Africa, which largely results from colonial suppression of vernacular architecture (VA) (Lidón de Miguel et al., 2021), is continued by foreign investors who equate industrial methods with social welfare (De Gregorio et al., 2023). Vernacular architecture (VA) aligns with sustainability principles by using local materials and reversible connections, reducing emissions and waste while boosting local resilience. It serves as a model for sustainable design amid climate change discussions. However, adapting VA faces challenges, including the loss of traditional skills, regulatory gaps, and modern comfort requirements, alongside concerns about deforestation and overuse of natural materials (Pardo, 2023). Precise knowledge regarding the availability and suitability of construction materials is often lacking.

Manual scans of natural resources offer insights into availability, distribution, and quality, guiding material selection and design for sustainable construction with minimal environmental impact. A recent article on a harvest map approach in Zambia highlights sustainable resources, such as raw earth, plant fibres, and wood, for local architecture (De Gregorio et al., 2023). Architects at "superuse" employ resource harvest mapping as a design strategy, scanning for reusable materials (Superuse Studio, 2024). However, research on mapping natural resources in vernacular architecture is limited. This publication examines underutilized local resources like soil, timber, thatching grass, and fibres in Nyangoma Kogelo, Siaya County in Kenya, highlighting their potential for sustainable construction. Siaya County is an intriguing area for study due to its rich cultural heritage, diverse ecological resources, and unique architectural practices of the Luo ethnic group, offering valuable insights into sustainable construction methods that integrate local materials and traditions.

Geographical Location

The village Nyangoma Kogelo in Siaya County, western Kenya, is about 60 km northwest of Kisumu, on Lake Victoria's shores (Fig. 1, Fig. 2). Nyangoma Kogelo, part of the Luo Nyanza region, features rolling hills near the Yala River basin feeding into Lake Victoria. At 1,307 m elevation, it has a cooler climate than lower lake areas and is surrounded by farmland growing maize, millet, and sorghum.



Introduction

Case Study Area

Fig. 1

Schematic map of Kenya

Fig. 2

Schematic map of Siaya County

Within a radius of 50km around Nyangoma, the Wetlands are situated close to Victoria Lake. The Kakamega Forest is about 60km and the Yala River is about 2 km away from the village center of Nyangoma (Fig. 3).

Fig. 3

Map of Siaya County; 5km, 20km, and 50km distances to Nyangoma (Esri, DeLorme, et al., 2024)



Climate

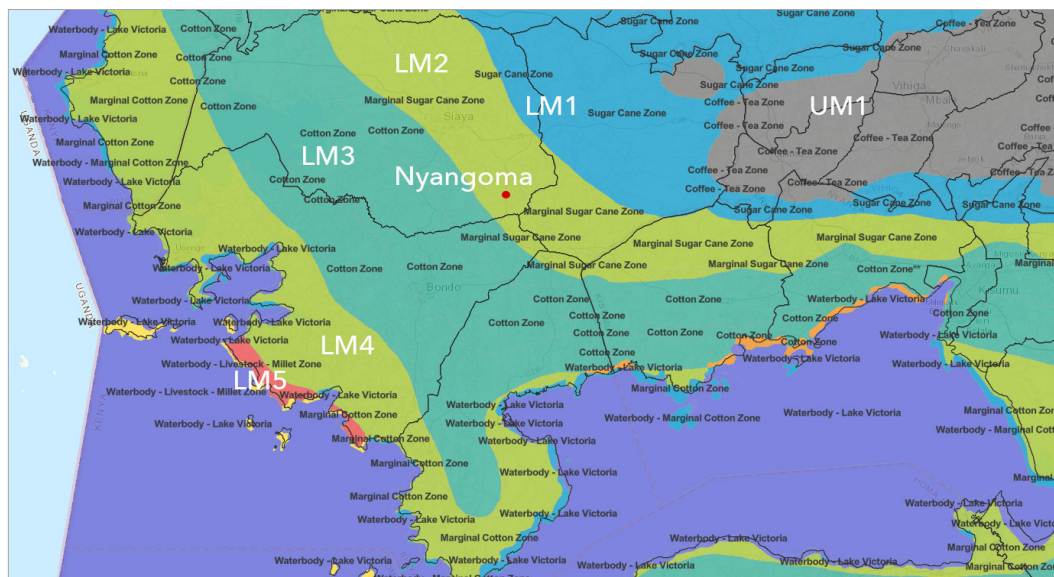
Nyangoma Kogelo, in central Siaya County, Kenya, has a tropical savanna climate with distinct wet and dry seasons influencing agriculture and daily life (Kong'ani et al., 2018).

The area receives 450-1,400 mm of rainfall annually, with long rains in April-May and short rains in October-December, essential for key crops like maize, sorghum, and vegetables, supporting local sustenance and income (Wabwire et al., 2020). The dry season, from September to February, brings high temperatures and low rainfall, challenging water availability and agriculture (Mera, 2018). Lake Victoria influences the region's climate, moderating temperatures and creating a bi-modal rainfall pattern. In Nyangoma Kogelo, annual temperatures range from 17.4°C to 24.5°C, with January to March as the hottest months and July to August as the coolest.

Siaya County falls within the LM zone system (Fig. 4), ranging from LM1 to LM5. LM1 areas are the most productive, with fertile soils, reliable water, and favourable climates, supporting intensive agriculture and livestock farming (MoALF., 2016).

Fig. 4

Agro-Ecological zone map of the case study area (Regional Centre for Mapping of Resource for Development, 2023)



LM zones around Nyangoma have a warm climate, with temperatures of 21-24°C. The nearby UM zone, at 1,200-1,500 m, averages 18-20°C. Humidity decreases from LM1 to LM5, matching UM1 with LM1. Rainfall ranges from 1,100-2,700 mm in LM1 to 450-900 mm in LM5 (Republic of Kenya, Ministry of Agriculture Kenya Soil Survey, Nairobi., 1980).

Methods

Comprehending the local climate is vital for the effective utilization of regional natural resources in construction. It informs the selection of flora, availability of materials, and design of structures resilient to climatic conditions. Comprehensive research into the regional climate and agro-ecological zones was undertaken. Analyses of pre-colonial Luo vernacular architecture, conducted via site visits, artisan interviews, and literature reviews, provide insights into the efficacy of historically utilized local materials. This analysis also evaluates the potential of alternative biomaterials. Table 1 outlines the research steps, associated indicators, and employed methodologies.

Topic	What?	Indicators	Methodology
1. Climate	Climate zone/ago-ecological zone	Temperature Humidity	Literature review
2. Identification of vernacular architecture	Vernacular architecture of Luo community in Siaya county	Techniques, materials and craftsmanship	Literature review, site visits, site observations, interviews of local artisans
3. Natural resources	Availability of natural resources, defining mechanical properties and life cycle	Soil, timber, grass, fibres	Literature review, analysis of geographical maps and primary sector

Table 1
Study roadmap

Resources of the Luo Vernacular Architecture

Fig. 5 indicates a sketch of a Luo traditional vernacular hut section. Roof rafters are crafted from Siala (*Markhamia lutea*) or Sisal (*Agave sisalana*) poles, with unprocessed battens 'Fittos' from Siala branches, joined by Sisal fibre cords. The thatched roof uses 'See' or 'Yueyue' grasses. A Wattle and Daub wall system uses 50-80cm deep Siala supports and a Sisal-tied mesh. The earth wall consists of four layers: Ruako, Ruodho, Yuoyo (soil-water mixes), and Lango (with soil, water, cow dung, and optional wood ash). Table 2 and Fig. 6 summarize the resources required for a traditional Luo hut with a ground floor measuring 6 m in diameter and 28.3 m² in area, based on the following construction assumptions: 90 cm pole spacing, 40° roof pitch, and 75 cm overhang. All assumed measurements are indicated in Fig. 7.

Results

Material	Total volume [m ³]	Dry bulk density [kg/m ³]	Weight [kg]	Percentage share
<i>Markhamia lutea (siala)</i>	1,42	684 (Sseremba et al., 2010)	973.84	5,91 %
<i>Agave sisalana</i>	0,004	1,160 (Material Archiv, 2024)	4.66	0,03 %
Soil	5,98	1,300.00 (assumption)	7,771.88	47,20 %
Gravel	3,49	2,000.00 (assumption)	6,974.22	42,35 %
Cow dung	0,36	380 (Raphael Vasconcelos Pachamama et al., 2020)	137.25	0,83 %
Grass	17,30	35 (assumption)	605,55	3,68 %
Total			16,467.40	100 %

Table 2
Percentage of materials by weight in a vernacular Luo hut

Fig. 5

Section of a Luo hut

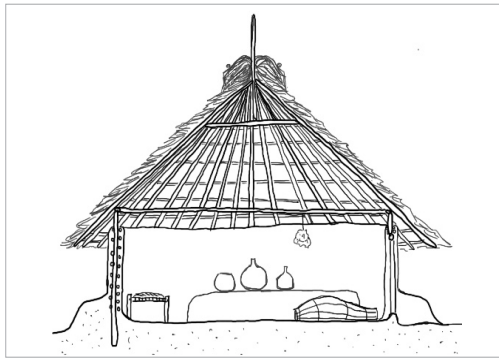


Fig. 6

Percentage of materials
by weight in a vernacular
Luo hut

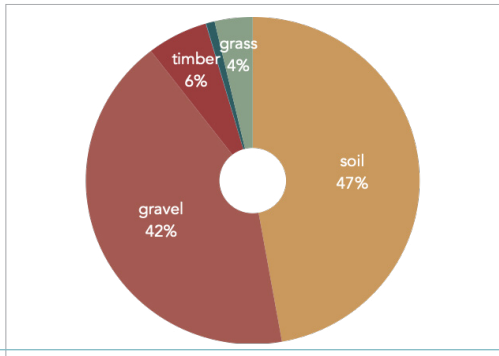


Fig. 7

Detail section of
traditional Luo wall and
roof construction

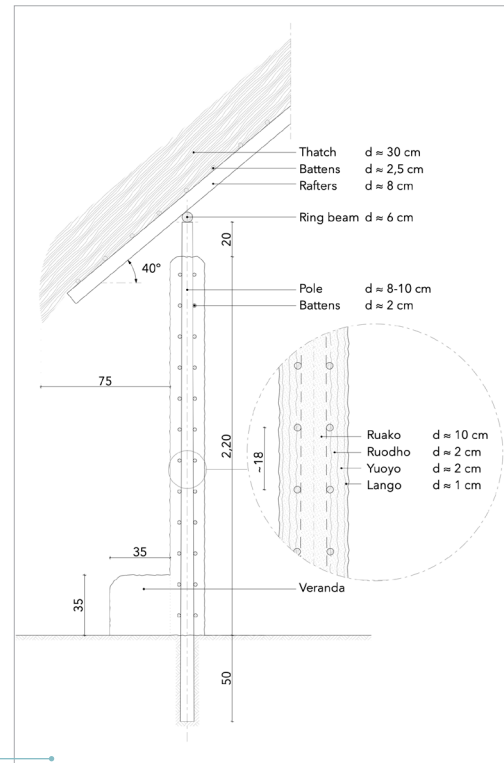
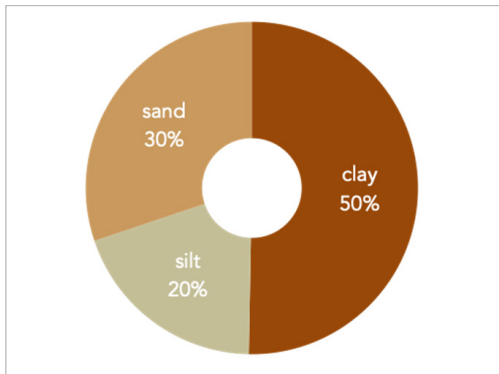


Fig. 8

Average distribution
of clay, sand, and silt
contents within a radius
of 3km around Nyangoma
centre



Natural Resources

Soil. ArcGIS and Esri environment maps were used to analyse Nyangoma Kogelo's soil, using machine learning to predict characteristics at a 250 m resolution from 230,000 soil profile observations (Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aergrid, et al., 2024). These maps reveal clay, sand, and silt content. A Esri point analysis, showing clay content varies from 46-55% within 3 km of central Nyangoma (Esri,

DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aergrid, et al., 2024). The silt content is between 17.2 and 22.5 % and the sand content between 27,7 and 33,2 % (Fig. 8). These values are preliminary and should be validated by laboratory tests for construction use.

Timber. According to Global Forest Watch, Alego Usonga spans 607 km². In 2010, it had 18% tree coverage, which declined by 0.2% by 2023. *Markhamia lutea*, *Grevillea robusta*, and *Eucalyptus* spp. are prevalent in the Siaya County (Imbaya et al., 2024). John Odiaga Oloo et. al published research in 2013 about tree species in Siaya sub-county, Bondo, which lies directly under the case study area of this research, Alego Usonga sub-county (Oloo et al., 2013). The following Table 3 shows indigenous and Table 4 exotic tree species that are usable for building construction and their distribution in Siaya sub-county, Bondo, according to Oloo's research.

Markhamia lutea/*Siala* (Fig. 9) used in the Luo vernacular architecture grows straight up to 10-15m in altitudes between 900-2,000m with a mean annual temperature of 12-27°C. "The tree is

drought resistant but cannot withstand waterlogging” (Orwa C et al., 2009). The following mechanical properties in Fig. 12 and Fig. 13 are for a four-year-old tree. *M. lutea* had the highest nail-holding power over *A. coriaria* and *C. albidum*. This is probably due to the higher density of fibres per unit area of *M. lutea* (5–20 fibres per mm²) compared to the other species that have less than 5 fibres per mm² (Sseremba et al., 2010).

Albizia coriaria can grow from 3 to 36 m high. A specific growth rate was not found; it is only said that it is a slow-growing tree (Ken Fern, 2022a). The literature review revealed a lower compression strength than *Markhamia Lutea*, besides the fact of higher density and slower-growing rate – a local validation is recommended.

Cassia siamea primarily reaches heights of 10 to 12 meters and is renowned for its medicinal properties. The tree yields hard,



Fig. 9

Roof structure with *Markhamia lutea* timber

termite-resistant wood, which, despite its challenging workability, is used for poles, posts, bridges, mine timbers, and in crafting joinery and decorative items from its heartwood (Camille, 2014; SSR, 2023), (Heuzé et al., 2019).

Grewia trichocarpa reaches up to 5 meters tall, thriving at 900–2,150 meters altitude. Its leaves are medicinal, timber is used for poles, flooring, and tool handles, and bark fibres are used for binding in traditional hut construction (Ken Fern, 2022b). The tree's mechanical properties and growth rate are undocumented.

Scientific name	Luo name / common name	Main use	Distribution
<i>Markhamia lutea</i>	Siala	Building, agro forestry	23,6 %
<i>Albizia coriaria</i>	Ober	Furniture	12,25 %
<i>Cassia siamea</i>	Oyieko / Iron wood	Building, shade	4,75 %
<i>Grewia trichocarpa</i>	Powo Ochol	Building	2,25 %

Table 3

Indigenous tree species for building in Siaya County (Oloo et al., 2013)

The following section will discuss two exotic tree species (Tab. 4) found in Siaya County.

Eucalyptus spp, originating from Australia and parts of Southeast Asia, is widely cultivated globally. In the Kenyan study area, the four key species (1) *Eucalyptus grandis* and (2) *Eucalyptus paniculata* are noted, with uses including poles, sleepers, flooring, bridge construction, fuelwood, and charcoal (P.O. Oballa et al., 2010), and (3) *Eucalyptus maculata* utilised for railway line sleepers (P.O. Oballa et al., 2010) is termite resistant (CUTEK, 2024)). Close to the Victoria Lake and the wetlands (4) *Eucalyptus camaldulensis* can be found. *E. camaldulensis* is a hardwood and relatively termite-resistant (P.O. Oballa et al., 2010).

Grevillea robusta is native to Australia. It can reach a height of 20 m with a width up to 25cm (Orwa et al., 2009b). *Grevillea* is primarily used for timber, poles, and fuelwood, and serves as bee forage, mulch, for soil conservation, windbreaks, shade, and decoration. Farmers are advised to convert *Grevillea* into timber for higher returns (Njuguna et al., 2014). The diagram (Fig. 10) illustrates a comparison between the average maximum height and growth rate of locally found tree species. The fastest growing and tallest species is *E. grandis*, closely followed by *E. camaldulensis*. Both species exhibit slightly greater compressive strength than the traditionally used timber,

Markhamia lutea. Additionally, they have a significantly higher modulus of elasticity, with *E. grandis* having nearly three times the modulus compared to *Markhamia lutea*, as shown in Fig. 13. *E. paniculata* demonstrates the highest density, which corresponds with the greatest compressive strength, as depicted in Fig. 11, and Fig. 12.

In Luo vernacular architecture, *Agave sisalana* poles were also used for roofing. Sisal is described in the "Fibres" chapter, where the mechanical properties of the fibre is unknown. Also, bamboo as a timber material is discussed in the chapter "Grass", as it belongs to the *Poaceae* family.

Table 4

Exotic tree species for building in Siaya County

Scientific name	Luo name / common name	Main use	Distribution in Siaya county
<i>Eucalyptus spp</i>	Bawo	Building (timber, plywood, poles) (P.O. Oballa et al., 2010)	22,4 % (Oloo et al., 2013)
<i>Grevillea robusta</i>	Bole / Silky oak	Agro-forestry (Oloo et al., 2013)	16,38 % (Oloo et al., 2013)

Fig. 10

Local tree species – max. average height [m] and max. average growth rate [m/year]

Fig. 11

Local tree species – density [kg/m³]

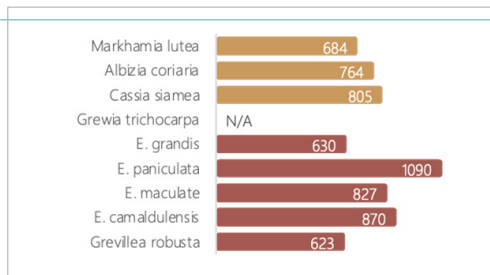


Fig. 12

Local tree species – Compression strength (parallel) [MPa]

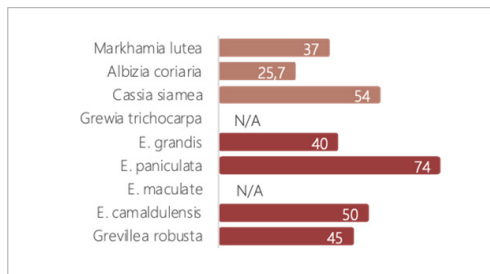
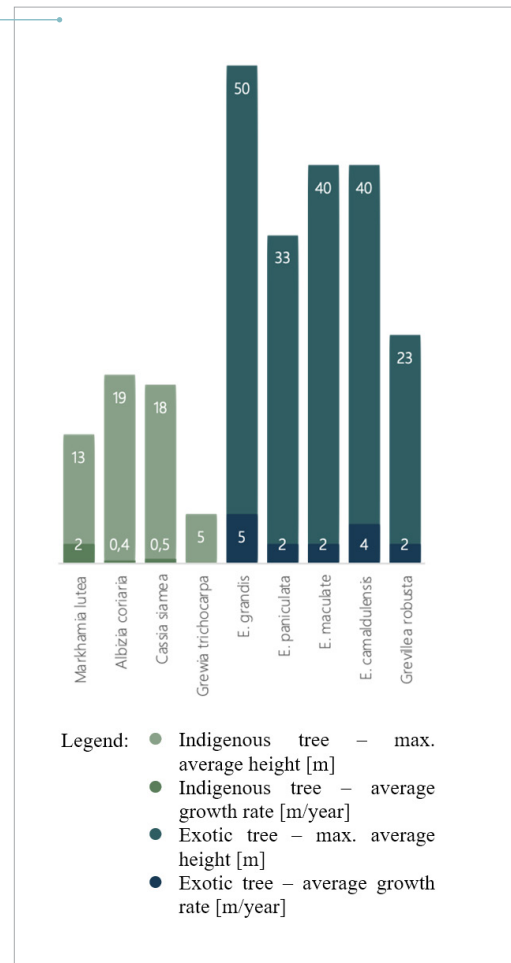
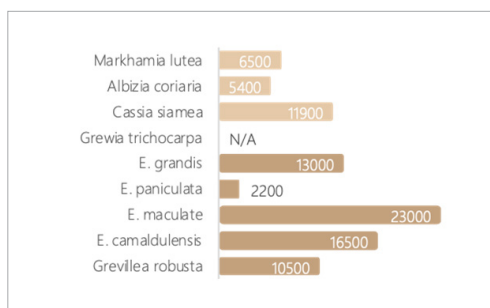


Fig. 13

Local tree species – Modulo of Elasticity (MOE) [MPa]



Grass

A qualitative literature review on *Poaceae* grasses used for thatching in Siaya County highlighted the lack of documentation of this ancient roofing method. During research in Nyangoma, interviews revealed a decline in skilled craftsmen, with only one artisan specializing in thatched

roofs using *Hyparrhenia hirta* ('See'). This grass, reaching up to 2.5 meters, grows mainly in late spring and autumn. It is tall for its type, though shorter than *Pennisetum purpureum* ('Napier' or 'Osinde'), which can reach 4 meters. (Fig. 14).

Pennisetum purpureum (Elephant grass, Uganda grass, Napier) is a hardy perennial native to sub-Saharan Africa. Widely cultivated in tropical and subtropical regions, it is a highly productive fodder crop, particularly recognized in Nyangoma (Maleko et al., 2019; Negawo et al., 2017). It is used as thatching material. However, according to "Safari Thatch" it is only 5-6 years durable in hot and humid areas (Safari Thatch, 2018). According to Obura et al., *Hyparrhenia rufa*, known in Luo as 'Yueyue' and referred to as 'Jaragua' or giant thatching grass, is widely used for thatching and erosion control in Kenya and other South African countries. It is a drought-resistant species and grows rapidly (Obura et al., 2011; Rojas-Sandoval & Acevedo-Rodríguez, 2014).

A survey in Isiolo and Samburu Counties, northern Kenya, found *Pennisetum mezianum*, *Chrysopogon plumulosus*, *Heteropogon contortus*, and *Sporobolus helvolus* suitable for thatching, with *Heteropogon contortus* ('Ombaki') regarded as the best option by locals (Omollo et al., 2023). This species can grow up to 1.50 meters (Fig. 14). According to Itzkan et al., it is called a "climate hero" in Zimbabwe for its increasing carbon sequestration (Soil4Climate, 2014). However, it is less common on heavy clay soils and in saline conditions (Dube, 2017). Spear grass serves purposes, like thatching, matting, and paper cellulose production (Heuzé V. et al., 2017).

Limited literature exists on *Pennisetum mezianum*, and its presence in Siaya County is uncertain. *Sporobolus helvolus* typically grows at altitudes of 10 to 760 meters, making it unsuitable for Siaya County (T. A. Cope & M. Thulin, 2008). A study by R. Cornelius et al. notes that *Chrysopogon plumulosus* is being replaced by *Sporobolus nervosus* in northern Kenya, and its status in Siaya County remains unclear (Cornelius & Schultka, 1997).

Cymbopogon spp. (in Luo: Osinde; lemongrass, Malabargrass) is not well-known in Siaya as a thatching material. It is mainly used for tea and food preparation. Nevertheless, it can be an interesting alternative to the traditional thatched roof. According to Strohbach et. al, this grass species lasted for 30 years as roofing in Omega (in the Bwabwata National Park), due to the oils contained in *Cymbopogon*, it does not seem to rot so quickly (Strohbach & Walters, 2015). In the National Museum of Nairobi, a broom is made of Osinde grass (National Museum of Kenya, 1969).

Chrysopogon zizanioides (Vetiver) has various benefits. It is used for soil and water conservation/regeneration and erosion control due to its long roots, which can extend down to 3 m (Bhuiyan, 2008; The Vetiver Network International, 2021c). This robust root system withstands both droughts

and waterlogging (The Vetiver Network International, 2021a). It can be used for rain-water harvesting (Green Action Sustainable Technology Group, n.d.). According to the Vetiver Network International, it is a long-lasting thatching material (up to 20 years) that can be made in two different thatching methods: Asian style with vetiver panels or European/African style using bundles (The Vetiver Network International, 2021b). The Vetiver Network Int. also provides a guide for thatching with Vetiver grass in South Africa. The Asian style of thatching can also be observed at the coastline of Kenya, i.e., in Lamu, made with palm reeds (Fig. 15). For thatching, the grass should have a minimum height of

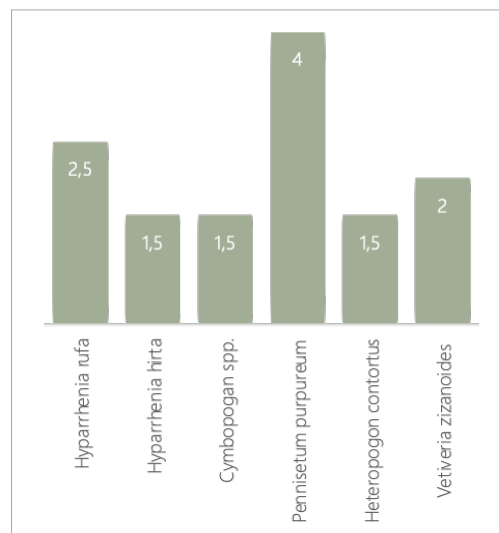


Fig. 14

Local grass types – max. height [m]

Fig. 15

Thatch roof with palm reeds (Asia style)



80 cm before harvesting (Thatchers association of South Africa, 2016), its max. growth height is up to 2m (Fig. 14).

According to an interview with a Kenyan architect and professor of building physics in Nairobi, the suggestion of investigating further water reed/lake grasses, as it is a thick and more water-resistant grass, came up. At Lake Victoria, mainly *Papyrus* (*Cyperus papyrus*), *Phragmites Mauritius*, and *Typha capensis* are growing (Wakwabi et al., n.d.). All three species can be used for construction and thatching. However, the reeds in the Victoria basin are threatened by overharvesting, wetland burning, and riverbanks' degradation

(Whitney, C.W. et al., n.d.). Furthermore, the grasses near the Yala River could also be examined more closely in another study. Sustainable economic concepts must be developed for further consideration as a building material.

Bamboo. Due to its fast-growing and strong mechanical properties, several studies have been published about the economic and ecological benefits of using bamboo as a building material. Often, these studies refer to bamboo architecture in Latin America and Asia (Krötsch, 2013; Ochieng, 2022). In 2022, Kenya published its latest "National Bamboo Policy" in which the government defined objectives to increase the production and value chains of bamboo, research about uses for bamboo, and implement a Bamboo policy (Ministry of Environment and Forestry, Kenya, 2022). Regions in Kenya like Mt Elgon, Cherang'any, Mau, the Aberdare Range, and Mt Kenya are still covered with the Indigenous bamboo *Oldenia alpina* (Krötsch, 2013; Muchiri & Muga, 2021). Together, these wild bamboo forests cover around 133,273 ha. According to the "International Bamboo And Rattan Organization", 5 million tons of Carbon are stored in these forests (Muchiri & Muga, 2021). Bamboo poles can be used as an alternative timber structure material, but are also manufactured as different engineered bamboo products, like Plybamboo, Bamboo Laminated Lumber, Bamboo scrimber, Flattened Bamboo, and Bamboo OSB (Habibi et al., 2023). However, these products contain adhesives that prevent natural degradation at the end of the life cycle.

The bamboo species *Oldenia alpina* at an altitude of 2,300 – 3,200 m (Lohani et al., 2023) is therefore not suitable for cultivating purposes in Siaya County. Other indigenous species in Kenya are found, like *Hickelia Africana* (origin Tanzania), *O. latifolia*, *O. buchwaldii*, and *Pseudosasa amabilis*. Introduced species are *B. bambos*, *B. lako*, *B. nutans*, *B. tulda*, *B. vulgaris* (*B. vulgaris* var. *vittata*), *D. asper*, *D. brandisii*, *D. giganteus*, *D. hamiltonii*, *D. membranaceus*, *D. strictus*, *O. abyssinica*, *P. edulis*, *P. nigra* var. *henonis*, *Schizostachyum pergracile*, *Shibataea kumasaca*, and *T. siamensis* (Bahru & Ding, 2021). The individual distribution is unknown. In south Nyanza (south of Victoria Lake), research about survival rates of two bamboo species in former tobacco growing areas was investigated – *B. vulgaris* has a survival rate of 94 % and *D. giganteus* of 70%. Additionally, they found out that bamboo grows better in non-waterlogging areas (like tobacco farms). Both species prefer moist soils (Kibwage et al., n.d.). *P. edulis* (Moso) grows well in altitudes of 1,200-1,500m above sea level and is a common construction bamboo in China, where it can grow 23 m high with a diameter of 8-18cm (BambooU, 2023). Due to its high compressive strength (up to 69.9 MPa), it is useful for heavy construction (Ben Drury et al., 2023). The Lake Victoria Basin Commission promotes the cultivation of *D. gigantea* (Lake Victoria Basin Commission, 2022). However, there is no overview of the bamboo fields that have already been planted. *D. gigantea* naturally thrives in humid tropical highlands or slopes up to 1,200 m altitude and can also flourish in lowland areas

with high humidity on rich loam or alluvial soil (Stéphane Schröder, 2024). Due to the strong mechanical properties and rapid growth rate of bamboo, it is recommended that the cultivation of bamboo in Siaya County and the use of bamboo in future architecture be further explored.

Fibres

Six different fibre types (listed in Table 5), *Agave Sisalana* (Sisal), *Euphorbia tirucalli*, *Combretum*, *Saccarum officinarum* (sugar cane), as well as the leaves of *Musa* (Banana) and *Ananas comosus* (Ananas), are considered in the following section. Except for the *Agave Sisalana*, which is originally from Mexico, all fibre plants are indigenous.

In traditional Luo architecture, *Agave sisalana* (Fig. 16) fibres were used to tie rafters to the

Scientific name	Luo name / common name	Main use	Distribution
<i>Agave sisalana</i>	Sisal	Ropes, twine	-
<i>Euphorbia tirucalli</i>	Ojuok / finger euphorbia	Fencing, latex, fuel, glue, fibres	8,18 % (Oloo et al., 2013) of Siaya county area
<i>Combretum</i>	Keyo / river bushwillow	Windbreak, fibres	4,76 % (Oloo et al., 2013) of Siaya county area
<i>Saccharum officinarum</i>	Sugar cane	Bagasse as composite material for bricks	-
<i>Musa</i>	Banana fibres	Reinforcement in concrete	-
<i>Ananas comosus</i>	Pineapple leaves fibres	Reinforcement in concrete	-

Table 5
Fibres in Siaya county

superstructure before the advent of nails. The process involves pulling apart, drying, and re-soaking the fibres to form rope. While the leaf sap is non-toxic, it can irritate the skin, so handling with care is recommended. Recent studies highlight sisal's benefits as a fibre additive in concrete, enhancing compression strength (Agro Pro Limited, 2024; Selvam et al., 2024). Alene et. al investigated the compression strength enhancement of mixing Sisal fibre into mud bricks. They found out that 1% of sisal fibre in the mixture can double the strength of the mud brick (Alene et al., 2022).

Euphorbia tirucalli is a recommended tree for hedges and fencing (Fig. 17). It was used traditionally to surround the Luo Homestead. It can grow 6 to 9 m high and tolerate droughts and dry soil. Its latex has an adhesive property, but it is toxic and can cause skin irritation. The latex “has been used in the linoleum, oilskin, and leather cloth industries.” (Missouri Botanical Garden, 2022). The fibres can be used for the textile industry (Azanaw & Ketema, 2022; Vinod et al., 2023). Due to the adhesive property of the *Euphorbia* leaf fluid, further research into the usability of this to produce new fibre bricks would be interesting, like the



Fig. 16
Agave Sisalana in Nyangoma

Fig. 17

Euphorbia tirucalli in
Nyangoma



“sugarcrete”. Grimshaw and the University of East London (UEL) developed “Sugarcrete” made of sugarcane (*Saccharum officinarum*) bagasse with mineral-based binders to create construction bricks (University of East London, 2024). In March 2022, a “Business Daily” newspaper published a proposed plan to open a sugar cane factory in Alego Usonga, noting that 18,400 acres of land will be planted with sugar cane and could produce 1,250 tons of cane per day (TCD), expandable to 2,500 TCD (Business Daily Africa, 2022). Updates on this plan are unknown. In Kenya, Combretum is traditionally used to craft donkey panniers and wicker baskets for carrying milk vessels. In Senegal, it plays an in creating fish lures (Orwa et al., 2009a). Banana and pineapple leaf fibres

are valued in construction for their mechanical properties. Both fruits thrive in Siaya County. According to KARLO, Kenya produced 247,000 metric tons of pineapple in 2021, with a projected annual growth of 2.3% (Kenya News Agency, 2023).

Discussion

Geographical analysis reveals a 50% clay content in the soil, indicating a rich loamy texture. For most earth-building techniques, 15–30% clay is adequate. Detailed composition should be verified through laboratory analysis. Based on results, additional aggregates may be needed to optimize the soil for specific building applications.

Markhamia lutea ('Siala') is the most prevalent indigenous wood, traditionally used in Luo architecture, noted for its rapid growth and favourable mechanical properties, ideal for sustainable forestry and construction. Despite literature claims of termite resistance, site visits revealed infestations, highlighting the need for protective methods, i.e., surface charring (Shou Sugi Ban). *Cassia siamea*, with nearly double the modulus of elasticity, grows more slowly and could be used in high-load areas. Exotic species like *Eucalyptus* and *Grevillea robusta* grow rapidly and offer high mechanical strength and density, making them viable alternatives or supplements. However, their environmental impact must be assessed. Additionally, *bamboo*, with its fast growth and excellent mechanical properties, is a promising timber alternative, already successfully used in Asia and Latin America.

The grass analysis focused on cataloguing species suitable for roofing. Four potential thatching grasses were identified during site visits: *Hyparrhenia hirta* ('See'), *Hyparrhenia rufa* ('Yueyue'), *Cymbopogon* ('Osinde'), and *Chrysopogon zizanioides* ('Vetiver'). 'See' is commonly used in Nyangoma, but 'Osinde' and 'Vetiver' could offer more durability and warrant further study. Literature review also highlighted *Pennisetum purpureum* ('Napier') and *Heteropogon contortus* ('Ombaki'), though 'Napier' is less viable, lasting only up to six years, and 'Ombaki' lacks a comprehensive evaluation. Overall, research on the durability and processing of these grasses is limited, indicating a need for further investigation. Additionally, exploring the sustainable use of grasses from Lake Victoria and the Yala River should be prioritized.

Various fibres have great potential in reinforcing clay construction and other building applications. The UEL's "sugarcrete" blocks and indigenous fibres could enhance earth-building and pressed fibre blocks. *Euphorbia* leaf adhesive may also be suitable. Banana and pineapple leaf fibres, used in concrete, could be tested in earth construction. Sisal, traditionally used in wooden ties, was replaced by nails; its perceived declining robustness is unverified. Studying sisal use in Mexico might offer new processing techniques.

This resource scan, grounded in the study of Luo traditional architecture, local interviews, and extensive literature review, may have overlooked other valuable plant and tree species for building practices in the region.

Using local materials and craftsmanship extends beyond environmental sustainability—it preserves culture, bolsters local economies, and tailors architecture to a community's unique needs, context, and climate. These principles are essential for projects emphasizing renewable materials and sustainable design, necessitating awareness of local resources among construction stakeholders. Siaya County's climate is ideal for growing diverse plants valuable for future architecture, provided they are managed sustainably. Exploring bamboo and eucalyptus as building materials and testing local grasses for roofing durability are promising avenues. Utilizing natural fibres offers innovation potential, but considerations of climate change and insect challenges remain crucial. To enhance the use of natural materials, developing metrics to estimate resource needs for sustainable forestry and agriculture is necessary. This underscores the vital importance of research into natural materials in construction.

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Conclusions

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