Diplomarbeit

For Example Bowa Hill - On the Transformation of Contemporary Vernacular Architecture: Building Culture and Materials

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unter der Leitung von
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Abstract

EN For Example Bowa Hill is an applied research project focusing on vernacular building construction in the Central Region of Uganda. Against the background of a building culture that is still characterised by anonymous architecture, the work attempts to understand transformative processes and to examine common building techniques currently in use. In the context of an exemplary planning task for a center for sustainable agriculture, case study buildings are developed to investigate the possibilities of an incremental transformation of the contemporary vernacular typology. Parametric building simulations are used to determine the influence of various factors on thermal comfort. The findings serve as a basis for the subsequent design.

Apart from minor deviations, the construction of the largely conventional building shells provides further insights into construction techniques and processes. A series of material experiments regarding roof, ceiling, wall, and floor constructions is used to develop alternatives to conventional building components from industrial materials. These alternatives are applied in the completion of the buildings. To allow for wide applicability, the experiments primarily use locally available (historically traditional) resources and attempt to take into account both craft practices and cultural values.

Finally, the quantitative results of a comprehensive Life Cycle Analysis are linked to the theoretical findings of the research and the observations made during the construction process. While from a technical point of view, a radical reduction of the building's environmental impact would be possible through the intensive use of locally available renewable resources, the entailed typological changes imply a multitude of challenges, that cannot be resolved at the level of architecture alone. The example of the case study buildings shows that already small measures can lead to a significant environmental impact reduction and improved thermal comfort. Given the increasing importance of status value and the limited influence of architects and engineers on local value systems, the integration into cultural patterns seems an appropriate approach, whereby a diversification of semi-industrialised building materials from renewable resources could lead to a transformation of collective building practices.

GER For Example Bowa Hill ist ein angewandtes Forschungsprojekt, das sich mit Formen des vernakularen Bauens in der Zentralen Region von Uganda auseinandersetzt. Vor dem Hintergrund einer auch heute noch von anonymer Architektur geprägten Baukultur versucht die Arbeit, zunächst transformative Prozesse zu begreifen und ein Verständnis über die gegenwärtig gebräuchlichen Bautechniken zu erlangen. Im Rahmen einer beispielhaften Planungsaufgabe eines Zentrums für nachhaltige Landwirtschaft werden Mustergebäude entwickelt, die der Untersuchung der Möglichkeiten einer inkrementellen Transformation der zeitgenössischen Vernakular-Typologie dienen. Mittels parametrischer Gebäudesimulationen wird der Einfluss unterschiedlicher Faktoren auf den thermischen Komfort ermittelt und die Erkenntnisse auf die Planung übertragen.

Die Errichtung der bis auf wenige Abweichungen konventionellen Rohbauten soll weitere Einblicke in Bautechniken und -abläufe erlauben. Anhand einer Reihe von Materialexperimenten zu den Bauteilen Dach, Decke, Wand und Boden werden für den sukzessiven Ausbau der Hüllen Alternativen zu konventionellen Bauteilaufbauten entwickelt. Im Sinn einer allgemeinen Übertragbarkeit, verwenden die Experimente vorwiegend lokal verfügbare (historisch traditionelle) Ressourcen und versuchen sowohl handwerkliche Praktiken als auch kulturelle Wertvorstellungen zu berücksichtigen.

Abschließend werden die quantitativen Ergebnisse einer umfassenden Lebenszyklusanalyse den theoretischen Erkenntnissen der Recherche und den Beobachtungen der Umsetzung gegenübergestellt. Es zeigt sich, dass aus bautechnischer Sicht unter ausschließlicher Verwendung lokaler, nachhaltiger Baustoffe eine weitreichende Emissionsreduktion möglich wäre. Die damit verbundenen typologischen Veränderungen implizieren jedoch eine Vielzahl an Herausforderungen. Am Beispiel der Mustergebäude lässt sich ablesen, dass bereits weitaus geringere Maßnahmen zu einer signifikanten Reduktion der Umwelt-belastung bei gleichzeitiger Erhöhung des thermischen Komforts führen. Im Anbetracht der gesteigerten Bedeutung von Statuswert und der begrenzten Möglichkeit der Einflussnahme von Architekten auf lokale Wertsysteme, könnte eine Diversifizierung der semi-industrialiserten Baustoffe unter der Verwendung erneuerbarer Ressourcen zu einer Transformation kollektiver Baupraktiken führen.

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The way we live our everyday lives is an expression of our convictions. For some people, water is what is used for washing cars, for others it makes the rice grow, for others still it purifies the body. The person who washes cars doesn't think about the rice and even less about the rituals; the river that flows below his house doesn't have the same meaning for him, that it has for the farmer or the priest. It's not only their use of water that separates them, it's an idea of water, a culture of water. The universe is not what we see, but what we believe. Beliefs generate practices.[1]

1 Clément, G. (2015) The Planetary Garden, p.12. Philadelphia: University of Pennsylvania Press.


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Introduction

In 2019, Lisa Alvanos and David Vogt contacted us and asked if we would be interested in participating in a project in the Central Region of Uganda. Together with their friend and local partner Paul Senoga, they had acquired 4 hectares of steep and barren land called "Bowa Hill" on which they planned to build a local centre for sustainable agriculture. The project was going to focus on experimenting with alternative cultivation techniques, biodiversity as well as local knowledge transfer and cooperative trading practices. An exact time-frame had not been set and also most programmatic details were still to be discussed. Although, or probably because, it was unclear what exactly our tasks as planners would be, the project seemed a suitable opportunity for a joint thesis.
We agreed from the start that Bowa Hill should not only be a design-build project in the literal sense, where something is planned and then realised. In the context of an academic thesis, it seemed more consistent to turn the planning task into an opportunity for a wider discussion, addressing general questions about architecture in the Central Region of Uganda and building in a tropical environment. In line with the basic ideas of the centre for sustainable agriculture, we suggested that also the architecture of Bowa Hill could be considered experimental. As part of a larger applied research project the design of case study buildings could include both project-specific aspects and general assertions.
Looking at the development of architecture in Uganda, it is striking that, compared to other emerging African countries, there does not seem to be a distinct contemporary architectural discourse.[1] In the light of a building culture that is nevertheless undergoing significant change, the question arises at which level transformation is negotiated. Particularly in the more affluent Central Region of Uganda, historical building techniques are almost non-existent[2], with traditional, regenerative building resources being replaced by energy-intensive, industrialised building materials.[3] Although the new construction methods have led to a partial professionalisation of the building sector, the essence of contemporary architecture remains anonymous and collective. Still today, most of Uganda's built environment is non-engineered or in the words of architectural theorist Berhard Rudofsky, "architecture without architects[4]".

Against this background, the most fundamental question is whether and how architects or engineers can contribute to the transformation of anonymous architecture. Given the scarcity of information on the subject, we want to start the research by gaining a basic understanding of the local building culture and underlying transformative processes. Furthermore we want to pursue two specific research questions:
1. To what extent and with which measures can the thermal comfort of contemporary anonymous architecture be improved? 2. To what extent and with what measures can the ecological impact be reduced? All research questions should be analysed on both theoretical and practical levels on the example of the case study buildings.

One Book, two Authors

The thesis *For Example Bowa Hill* was developed in collaboration between Benedikt Mass and Maximilian Weidacher over a period of 3 years. Subsumed under the project title For example Bowa Hill, the work is formally published in two separate theses under two different subtitles which reflect the authors' main focus. However, it was decided to combine the individual focal points into a single thematic unit, and each publication contains the work of both authors for the sake of completeness. Based on personal backgrounds and respective expertise, Maximilian Weidacher is primarily concerned with the local anonymous building culture, construction practices and the use of resources, while Benedikt Mass focuses on the analysis and evaluation of thermal comfort and ecological implications. As documented in the table of contents, the largest part of the work can be clearly attributed to one author or the other, yet it is always the close, interrelated collaboration that has formed the basis of all the individual analyses. The book *For Example Bowa Hill* summarises the collaborative working process and is structured around the four project phases of research, design, construction and evaluation.

The extensive research forms the first part of the thesis. Setting out from the Great African Rift Valley and beyond we gradually approach the Central Region of Uganda and the field of architecture.

The second phase can be divided into a general pre-design and a specific design part. The results of the pre-design assessments by Benedikt Mass form the basis for the subsequent planning of the case study buildings

fig.1 Satelite image of East Africa; landscape and countries.

on Bowa Hill. In the design, Benedikt Mass worked on the spatial organisation of the site and the settlement structure, while the individual buildings were developed by Maximilian Weidacher. Inextricably linked, both levels, the spatial organisation and the architectural design, were addressed simultaneously and are therefore summarised in a single chapter. Since the study of the emergence of anonymous architecture is itself a subject of applied research, part of the design questions were deliberately left open for the next phase, the realisation.

The third part of the thesis follows the construction activities on Bowa Hill and the events surrounding them over a period of one year. The basis for the presentation of the observations and findings is the construction diary kept by Maximilian Weidacher, with a focus on the three-week "Building Workshop" field-research on Bowa Hill.

The fourth and last part, the evaluation, starts with further individual analyses and conclusions based on the previous project phases. The collaboratively written final chapter, On Transformation, contrasts the often conflicting practical and theoretical findings to draw general conclusions about the potential and the limits of the transformation of collective building practices.

1 Adengo, D. (2020) *Advocating for Architecture in Kampala* [online]. https://www.youtube.com/watch?v=X-OzezPrBNyM&t=366s (Accessed: 22 March 2023).

2 Moriset, S. (2020) *Introduction guide to the preservation of traditional thatching of the Buganda community in Uganda*, p. 5. Nairobi: UNESCO [online]. https://hal.science/hal-03220208/document (Accessed: 11 December 2021).

3 Oliver, P., et al. (1997) *Enceclopedia of Vernacular Architecture of the World*, pp. 1998. Cambridge: Cambridge University Press.

4 Rudofsky, B. (1964) *Architecture Without Architects*, p. 11. New York: Museum of Modern Art.

A

Research

Geography
East Africa and the Great African Rift

Benedikt Mass

The vast geological feature of the Great African Rift Valley has dominated and formed the landscape of Eastern Africa for millions of years. It stretches over thousands of kilometers from the arid coastal deserts of the Afar region in Ethiopia, home to the most ancient hominid fossils discovered by paleoanthropologists, to the tropical savannas of Mozambique. The Great Rift Valley encompasses the continent's highest mountain ranges as well as its largest and deepest water bodies, in themselves geographical formations of such scale that they affect and form local macro-climates.

The Great African Rift Valley

As we zoom into the center of the Great African Rift Valley, the lush green shores of Lake Victoria come into focus, with the area known to us as the country of Uganda, home to 46 million people and subject of this thesis, to its north. Since Uganda is a land-locked country in East Africa, it seems necessary to take a closer look on this geographically distinct eastern region of the continent.

The term Great African Rift Valley is a geographical term rather than a geological one, but as it happens, it is still widely used to describe a series of connected tectonic rifts that delineate the boundaries of the geographical region referred to as East Africa. A rift valley is a geological phenomenon formed between divergent tectonic plates, whose drifting apart results in a depression. In the East African context, rifting is caused by the African Plate breaking apart into smaller plates, with the Nubian Plate, encompassing the major part of the continent, to the west, and the Somali Plate to the east, separated by the Victoria and Rovouma Microplates, areas of no seismic activity apart from the tectonic faults that define their boundaries.[1, 2] Millions of years from now, these eastern plates will eventually form a new subcontinental peninsula or island, while the Afar Triangle will have sunken to the bottom of a shallow ocean formed by the expanding Red Sea.

Just as these plate tectonics allow geologists to predict future continental movement, they also serve as an explanation of how today's topography has formed over the aeons. North of the Lake Victoria Basin, the rifts bisect into an Eastern and a Western Rift Valley, along the geological fault lines of the Victora Microplate. Seismic and volcanic activity is high along rift faults, and extensive mountain ranges like the Rwenzoris, Mt. Elgon or the Kilimanjaro Range have formed as a result of these processes, as did the great East African lakes. Even today, these areas are prone to earthquakes, and the large volcanic ridges remain active. However, the center of the Victoria Microplate that encompasses Lake Victoria and the largest parts of Uganda and Northern Tanzania is free from major seismic events.[3]

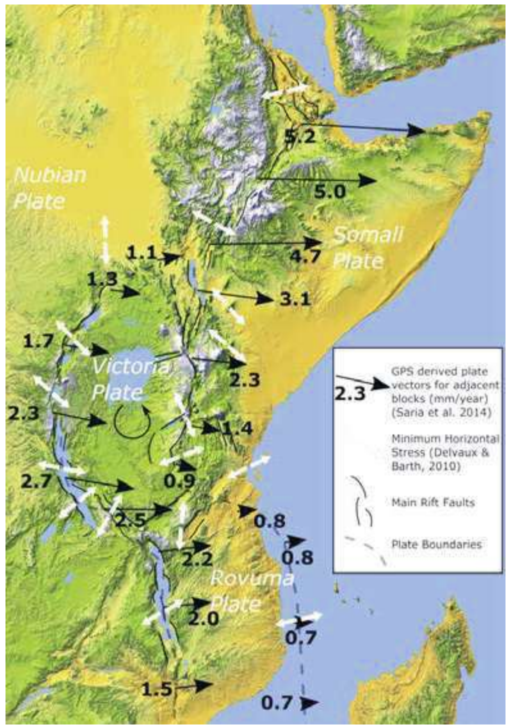


fig.1 Tectonics within the Great African Rift Valley.

fig.2 "Baganda Canoes on Lake Shore"; documented by John Roscoe around 1911.

As an additional geographical peculiarity, south of the Afar Triangle most of the Great African Rift valley is part of a broad region of high topographic altitude supported by the African Superplume, a convective anomaly in the earth's mantle pushing upwards[4] underneath the southern part of the continent. For this reason, apart from coastal regions, the largest share of East Africa, and of the whole continental land mass below a southern latitude of ten degrees is constituted of high plateaus of an elevation of more than 1000 metres above sea level.

As we go on reading about Uganda, we continue to stumble upon these geographical factors as a (partial) explanation of many of the region's distinct climatical, botanical, cultural and anthropological features, so from time to time, we will revisit these peculiarities in the following chapters.

The interlacustrine region

Uganda is divided in four administrative regions, that roughly coincide with the different geographical and climatic situations in the country. The White Nile River serves as a natural boundary that divides the Central and Western Region from the Northern and Eastern Region. While the Northern region gradually turns into an arid tropical dry savannah towards the borders with Kenya and South Sudan, the far reaches of both the Eastern and the Western Region are dominated by dense forest reserves around the snow-capped mountain ranges of Mount Elgon and the Rwenzoris. On the rolling hills of the more densely populated Central Area however, subsistence farmland, shrubs and open woodland form a finely tessellated mosaic intersected by a branching network of wetlands, consisting of papyrus swamps and open grasslands which become seasonal water bodies when flooded during the rainier months.

Uganda's Central Area is part of a larger expanse of rolling countryside with favorable environmental conditions, fertile soils and a tolerably hot climate with abundant precipitation, the so-called interlacustrine region[5], that stretches into Rwanda and Burundi as well as the northern parts of Tanzania. The region is characterised by large bodies of water linked by a network of rivers, streams and the wetlands described above. Uganda's main bodies of water are Lake Victoria and Lake Kyoga in the east of the country, and Lake Edward, Lake Kiwu and eventually Lake Tanganyika in the west.

We leave the compound of Hotel Networth in Wobulenzi at 6:30 shortly before sunrise. Today, we chose to walk to our site on Bowa Hill. It is still quiet at this time of day, as the muezzin has already concluded his first call for prayer, and relatively few vehicles pass us on their way to deliver whatever goods they are carrying. Instead of our usual chatter over the drone of the motorcycle engines, we hear roosters crowing in the distance, the song of a hundred birds and the low hum of myriad insects buzzing in the shrubs around us.

Branching off the main Kampala-Gulu road in the neighbouring village of Katikamu, we leave the only tarmac in the area and step on the omnipresent red soil so typical for the tropics. The new dirt road to Nakaseke, recently re-bulldozed after the heavy downpours of the wetter months, is still slippery from last night´s unexpected rains. As the sun rises, the relative cool of the night – our altitude is more than 1100 metres above sea level, after all – is quickly replaced by the equatorial heat of the day, and the mists of dawn begin to disperse.

We continue through Katikamu, and leaving the town, walking down the first of a succession of hills towards the papyrus swamp at the bottom between the settlements, we encounter the first drove

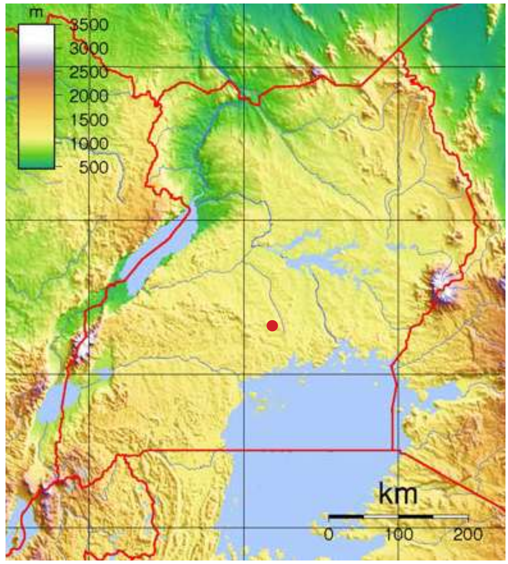


fig.3 Topography and water bodies of Uganda. The red dot indicates the location of Nakaseke district.

of schoolchildren in matching uniforms. "Mzungu! Mzungu!" we are greeted, accompanied by stifled – and not-so-stifled – laughter. And "mzungu" we are today, also in the most literal sense of the Luganda word: seemingly aimless wanderers, that may have underestimated how long it will take to walk the 25 kilometers to our building site.

Clay and Soil

Lateritic soils are a common feature of tropical environments, formed by a chemical weathering process that needs hot and humid environmental conditions, resulting in a soil rich in clay and iron oxides, hence the typical red color. Clay soils are ubiquitous throughout Uganda and have been used as a building material by different cultures since ancient times. While these soils are often indistinguishable at first sight from other, more sandy soils due to the predominant bright red color of the iron oxides they contain, a clay-rich, darker gray soil can be found in swampy areas. This loam is used by artisan brick makers to produce so-called clay bricks, fired bricks from a higher quality than the domestically produced mud bricks made from pretty much any soil available on one's plot of land.

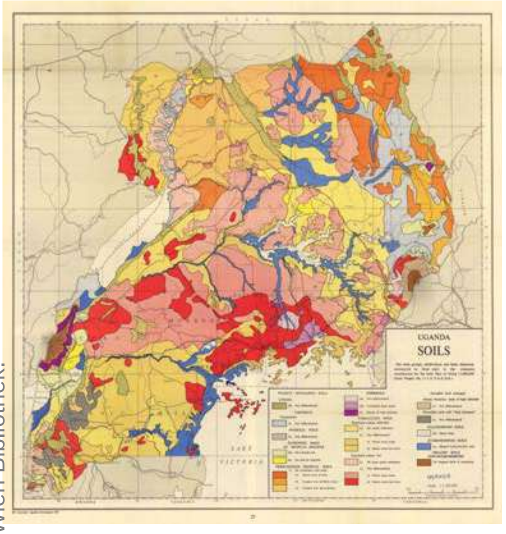


fig.4 (previous page) Brick production near Bowa Hill.
fig.5 Types of soil in Uganda.

When describing the vegetation of Uganda in a two-piece series of articles, botanist A.S. Thomas[6] also documents different soil types and their occurrence in relation to local topographies. The geography of the Central Region is one of undulating hills, and while a single hill has a very distinct pattern in which both soil and vegetation change depending on their location on the hill – whether on its top, on its gently or steeply sloping sides, or at its foot – in general, these patterns repeat on every hill with only minor variations. Therefore, the concept of the catena, defined as a succession of different zones on a single hill, is used as the measuring unit for describing the landscape of this region.[7] It encompasses only one hill, but - indefinitely multiplied - it serves as a pars pro toto for the whole landscape.

Incidentally, the traditional measure for distance used by the native Baganda people followed a similar notion, as British missionary and self-taught anthropologist John Roscoe observes: “In measuring length, they spoke of roads as being Mitala, which meant a stretch of road from one swamp to another, possibly including a hill.”[8]

Just as we did on our walks in the area, Thomas observed the distribution of red lateritic soils on gently sloping hillsides and flat hilltops, where human settlements are located, of fine, gray clays in the swamps are more sandy gray soils on the top of steep hills. Based on his observations, Thomas supports a hypothesis brought forth by other scholars of his time, namely that the formation of red, laterite soils may be correlated to anthropogenic factors. While an anthropogenic influence should not be completely dismissed, it seems unlikely that it can be made accountable for the omnipresence of lateritic soils in tropical areas worldwide, especially since the chemical weathering process, as described in detail for example by Tardy[9], takes part over the time frame of geological eras rather than that of human civilizations. Quite to the contrary however, the anthropogenic influence on the climate and vegetation of Uganda cannot be disputed – a notion we will return to in the following chapters.

1 Saria, E., et al. (2014) ‘Present-day kinematics of the East African Rift’, *Journal of Geophysical Research. Solid Earth*, 119, p. 3584–3600 [online], doi:10.1002/2013JB010901.
2 Delvaux, D., Barth, A. (2009) ‘African stress pattern from formal inversion of focal mechanism data’, *Tectonophysics*, 482(1–4), p.105-128 [online]. doi:10.1016/j.tecto.2009.05.009.
3 Saria et al. (2014) ‘Present-day kinematics of the East African Rift’.
4 Ibid.
5 Trowell, M., Wachsmann, K. P. (1953) *Tribal Crafts of Uganda*, p. 6. London: Oxford University Press.
6 Thomas, A.S. (1945) ‘The Vegetation of Some Hillsides in Uganda. Illustrations of Human Influence in Tropical Ecology. I’, *Journal of Ecology*, 33(1), p. 10-43 [online]. doi:10.2307/2256557.
7 Thomas, A.S. (1946) ‘The Vegetation of Some Hillsides in Uganda. Illustrations of Human Influence in Tropical Ecology. II’, *Journal of Ecology*, 33(2), pp. 153-172 [online]. Available at: https://www.jstor.org/stable/2256463 (Accessed: 03 April 2023).
8 Roscoe, J. (1911) *The Baganda: An Account of Their Native Customs and Beliefs*, p.39. Cambridge: Cambridge University Press.
9 Tardy, Y. (1997) *Petrology of laterites and tropical soils*. Rotterdam: A.A.Balkema.

Climate
Within the Intertropical
Convergence Zone

Benedikt Mass

Due to its high altitude and other geographical features described in the previous chapter, Uganda's climate is tropical, but more moderate in temperature and rainfall than regions of similar latitude. Apart from the mountain areas on the country's eastern and western borders and the more arid north, a biannual seasonal pattern of alternating dry and wet seasons can be observed in the largest parts of the country, correlating roughly with the seasonal movement of the Intertropical Convergence Zone (ITCZ). Unfortunately, this pattern is not exempt from climate change.

ITCZ

The ITCZ is a low-pressure region near the equator, formed by convergent trade winds from the north- and south-east. Where these winds meet, they force moist air upwards, resulting in cumulus clouds and heavy precipitation. As the relative orientation of the earth's axis towards the sun changes over the course of the planet's annual orbit, this zone moves north and south within the tropical region, passing over the equator twice a year during the time of the equinoxes.[1]

While over oceans precipitation patterns directly match the movement of the ITCZ, over land masses, topography is an additional factor that significantly influences macroclimatic conditions. Therefore, the movement of the ITCZ may diverge from that of tropical rain belts.[2] In the specific case of Uganda, and even more pronounced in the arid regions on the Horn of Africa, geographical peculiarities not only result in a more independent seasonal pattern, but also in unusually low precipitation, as compared to most other tropical regions.

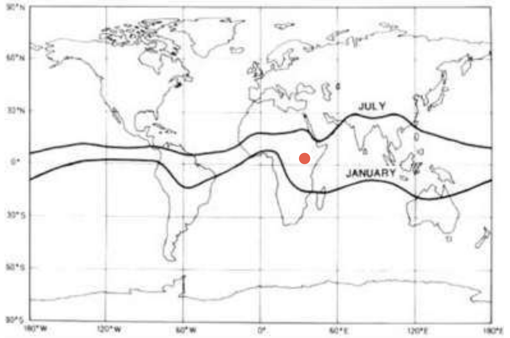


fig.1 Movement of the Intertropical Convergence Zone; the dot roughly corresponds to the location of Uganda.

Two main factors are responsible for this prevalence of drier climates in East Africa. On one hand, the Rwenzori mountains that form the border between Uganda and the Democratic Republic of the Congo serve as a natural barrier for moisture-saturated air moving over Africa from the West. On the other hand, reduced precipitation can be ascribed to air masses with low energetic potential moving across the continental land masses from the Indian Ocean.[3]

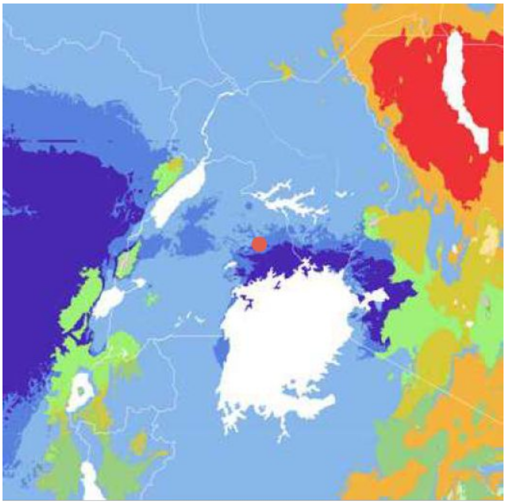
Tropical precipitation is caused mostly by moisture convection from surface evaporation. As relatively cool, dry air moves westwards from the open sea, it creates stable meteorological conditions suppressing convection. Therefore, relative humidity in higher atmospheric layers stays below saturation levels, effectively inhibiting the formation of rainclouds. During the rainy seasons, moisture content in these air masses is higher, due to higher sea surface temperatures over the Indian ocean. At the same time, the velocity of the air masses moving inland is lower. The combination of these two factors results in less stable atmospheric conditions in which rainclouds are more likely to form from local evaporation and the additional moisture from the Indian Ocean.[4]

Climate Zones in Uganda

The stabilizing effects of the atmospheric conditions described above are strongest over the Horn of Africa but can be observed in Uganda's semi-arid north-east as well. Generally, the different climate zones in Uganda correspond to the geographical peculiarities of the region. While temperate and even tundra climates do exist in narrow areas of high altitude around the mountains in the east and west of the country, most of Uganda is dominated by two climates. In the northern part of the country, a less humid climate is prevalent, with an annual cycle of only one wetter season during the time of boreal summer.

As we move closer to the shores of Lake Victoria, the pattern changes to the predominant biannual cycle, with a gradual increase in total seasonal rainfall. Shrouded in legend until its "discovery" for European geography by Sir Richard Francis Burton and John Hanning Speke in 1858, the second largest freshwater lake in the world is not only the source of the White Nile, but also a significant influence on the regional macroclimate. Large-scale evaporation from its waters transcends the stabilizing potential of the higher atmospheric layers, leading to the more humid climates of the Central Region.

The present Köppen-Geiger climate zones[5] over East Africa as shown in fig.2 correspond to the different phenomena already described in this chapter and illustrate the lacustrine influence on precipitation patterns. In close vicinity of Lake Victoria, tropical rainforest (indicated in dark blue) and monsoon climates (indicated in medium blue) are prevalent; most of the remaining country is a tropical savannah (indicated in light blue), with more pronounced dry seasons and generally lower precipitation. It should be noted here, however, that the Köppen-Geiger classifications tend to generalize, and differences within a single climate zone can be significant. Even though classified as a tropical rainforest climate, the climate around Lake Victoria more closely resembles that of the humid savannah of the interlacustrine region. The "typical" tropical rainforest climate, with a diurnal rather than a pronounced seasonal cycle, remains confined to the vast, densely canopied jungles of the Congo Basin, where heavy afternoon rains occur almost daily throughout the year. On the other hand, the savannah climate of the northeastern parts of the country more closely resembles that of the semi-arid steppe in Kenya and South Sudan, but again, the changes from humid to dry climates are very gradual.



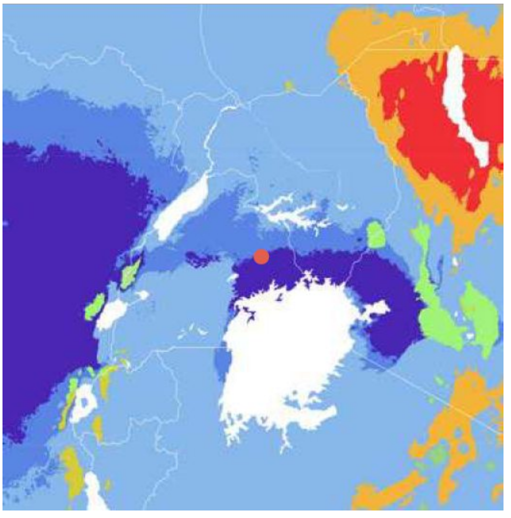


fig.2 (above) The present Köppen-Geiger climate zones of Uganda. The red dot indicates the location of Bowa Hill.
fig.3 (below) Future projection of climate zones.

Climate at Bowa Hill

Bowa Hill lies in an area where a monsoon climate gradually begins to turn in a tropical savannah climate. The climate graph in fig.4 shows a pronounced biannual seasonal pattern. While the mean temperature is relatively constant at around 22°C (with a variation of two degrees throughout the year), precipitation varies considerably. The annual cycle is characterised by two wet seasons with similar rainfall: the MAM- and the SON wet season. Between the two, rainfall is lower yet far from dry compared to other parts of the country. Relative humidity is high, with an average above 60% throughout the year except for the

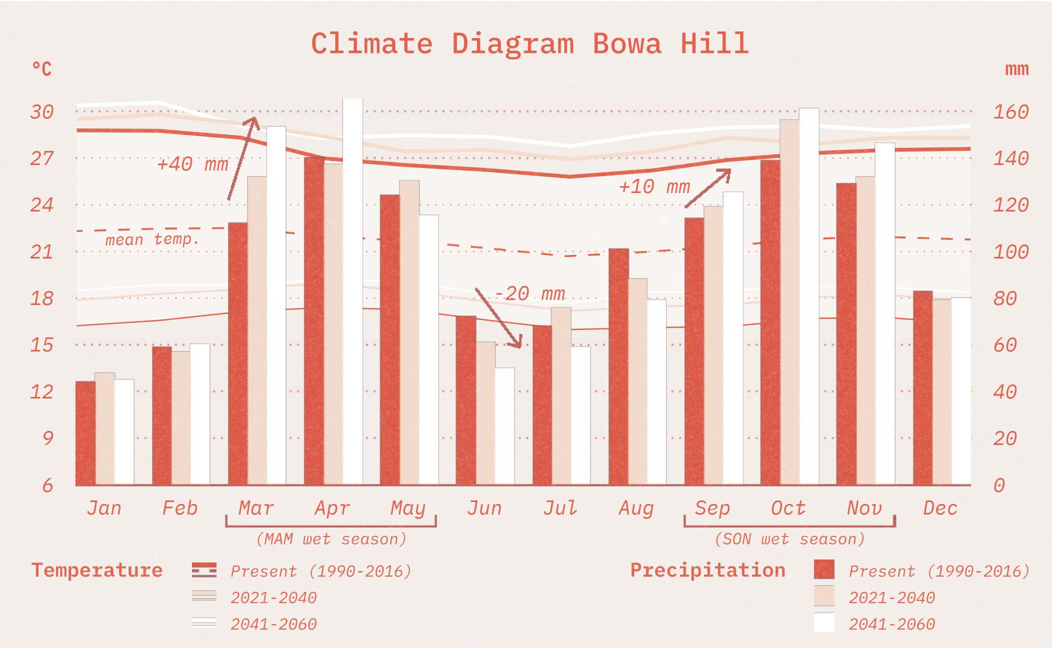


fig.4 Current climate graph and future climate projections for Bowa Hill.

two driest months of January and July, during which humidity is still above 50%. During the first wet season from March to May, humidity even reaches more than 90%.[6] While precipitation is significantly lower during the dry seasons, usually enough water is available, conserved in wetlands and restored by the remaining rains, and real droughts have been rare – and barely existence-threatening – in the past. In a sidenote regarding the biannual climate cycles, John Roscoe observed in 1911 that the Baganda people living in this area used a seasonal unit for the measurement of time quite different to our own: “A season of rain followed by drought made up a year; accordingly, the people regarded the year as consisting of six months, or moons, and they called it the mwaka”[7]. Roscoe also comments on the “pleasant” local climate with its “good and regular” rainfall, and subsequently goes so far as to propose that extensive cultivation of plantain trees by the local people may have positively influenced precipitation patterns and humidity in the interlacustrine region[8]. While Thomas[9] showed that the traditional layout of banana plantations may indeed counteract soil erosion and encourage accumulation of nutrients, Roscoe' s notion of their influence on local macroclimates is questionable. While it has been shown that biosphere-atmosphere feedbacks can indeed explain up to 30% of the variance in precipitation and surface radiation in some regions, no significant feedbacks have been found for Uganda.[10]

Climate change

Other anthropogenic influences however, tracing back predominantly to the fossil energy-fuelled societies of the global north, have shown to have a far greater impact on climatic conditions on both global and local scale. As the effects of these anthropogenic emissions have become more pronounced in recent decades, so have reports of failing rains, shifting wet seasons and generally more extreme and erratic seasonal patterns. In Uganda, anecdotal reports of more frequent heavy precipitation events during the dryer months leading to flooding are contrasted by reports of dry spells and heatwaves causing partial crop failures during the usually wetter months. Among others, Osbahr et al.[11] and Bomuhangi et al.[12] have tried to quantify the perceived effects of these weather events by empirically researching local farmers' observations, and Mubiru et al.[13] have shown that there are indeed observable trends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in rainfall variability. Especially the onset of rainy seasons tends to be increasingly uncertain, with rains more frequently starting later over the course of the last decades, effectively shortening the wet season and negatively affecting crop yields. Additionally, the total number of consecutive rain days during the rainy seasons has decreased, resulting either in lower overall precipitation or more extreme rainfall events, both of which adversely affect crop growth as well. Anthropogenic influences on global climate are evident and will lead to significant changes of the local climate in Uganda in the relatively near future. The temperature anomaly for the Central Region (fig.6) shows that mean temperatures have already risen by 1.5 degrees over the course of the last century. Future projections included in fig. 4 (previous page) show that in the next 40 years, the diurnal temperature range can be expected to shift by an additional two degrees.

The rains start early this year, or at least are unusually strong and frequent for the supposedly driest months, we are told by Moses, one of the drivers that take us to the building site every day. While we wait underneath the roof of a fruit stall on the side of the road for another torrent of rain to cease, he recounts that on the other hand, last October and November - the rainy season - were a lot drier than usual.

"But you know, this is the reason why God is great" he comments with a shrug that can imply either unflinching faith, hard-bitten irony or both. As smallholder farmers, he and his family have to deal with the fact that the rains are more erratic than they used to be, with many of the old certainties passed down by generations gone, and unsure about the turn of the seasons, about when to till and when to sow.

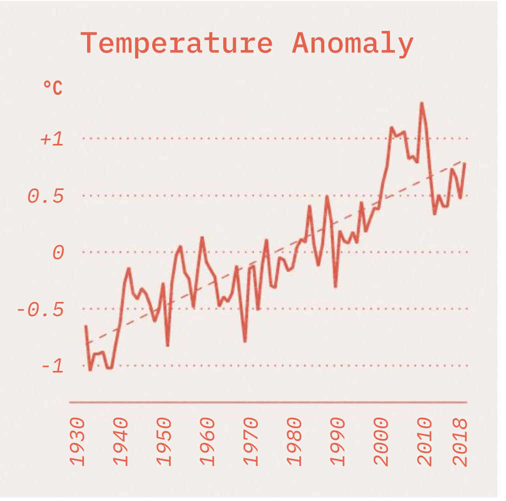

fig.5 (previous page) A shop selling plastic barrels in various sizes; the barrels are primarily used to store rain water.
fig.6 Temperature anomaly for the Central Region.

In the same projections, precipitation during the rainy seasons somewhat increases with no significant changes during dry seasons. The second rainy season may become the major wet season in future times. Therefore, the relative difference in precipitation between wet and dry seasons may increase, but without the looming threat of forthcoming water scarcity so omnipresent in many other regions of the world. Similar observations have been made by Nimusiima et al.[14], who also show that for the districts of Nakaseke and Nakasongola – both part of the Central Region – the first dry season in January may receive more precipitation in future decades, at least when averaged over the whole area of both districts.

Yang et al.[15] have shown that the CMIP climatic projection models may underestimate the effects responsible for low precipitation over East Africa, meaning that in turn future projections may be overestimating precipitation in Uganda. Older climate projection models based on the IPCC's RCP scenarios[16] project a future decrease in precipitation, with a decline of up to 20% in the Lake Victoria Basin[17]. Effectively, this means that uncertainties in the modelling of future precipitation may be larger than generally assumed. Additionally, even if average precipitation increases, so will the intensity, frequency and duration of droughts, as projected by Haile et al.[18].

Vulnerability

Both climate and meteorological sciences agree on the increase of extreme weather events as an additional effect of a global rise in temperature. Therefore, droughts and extensive rainfall, as opposite ends of a spectrum, are added to foreseeable heat stress as yet another, so far not entirely quantifiable risk factor. The effects of climate will significantly affect local wildlife and vegetation, and in consequence food security, assets and general livelihood of the human population as well.

If no adaptive measures were taken, Uganda's Ministry of Water and Environment estimates costs caused by issues related by climate change at US$273 - 437 billion until 2050.[19] While most of these costs are related to supply insecurities and infrastructural damages in the energy and water sector due to changing precipitation patterns – after all, Uganda is to the largest part reliant on hydropower for electricity generation – the third most significant factor is agriculture.[20] In Uganda, rainfed agriculture is practised almost exclusively, which makes the sector even more vulnerable to drought events, as no traditional irrigation systems or other measures for water conservation and management exist.[21] Even today, droughts and other extreme events already are of livelihood-threatening scale for many households. In 2019, 55% of households reported to have been affected by droughts, and another 42% by erratic, heavy rains and floods, with 41% reporting severe damage and 37% reporting food shortages resulting mainly from these events, with numbers on a comparable scale in 2018.[22] Finally, the costs accounted for in the GOU's 2015 study do not paint the full picture, as they neither include many additional consequences of food insecurities and potential famines, nor additional damages caused by the increased frequency of extreme events due to climate change.

Uganda rates 166 of 182 on the widely used ND-GAIN global vulnerability index.[23] Like most of the Global South, the country is particularly affected by climate change, while at the same time, adaptation and mitigation potential is low due to its low economic status. This is particularly tragic in light of the fact that at the same time, the country – again, like most of the Global South – contributes only the most marginal share to harmful global emissions.

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ad **fig. 4** Historical climate data obtained from Harris and Jones[f], downscaled with WorldClim 2.1.[g] Present data obtained from Fick and Hijmans (2017). Present data obtained from Fick and Hijmans.[a] Future projections for precipitation and temperature were made using CMIP 6 Data[b], downscaled with WorldClim 2.1 for the BCC-CSM2-MR global climate model[c] (chosen for its high spatial resolution), for a slightly pessimistic Shared Socioeconomic Pathway (SSP370).[d] The SSP370 scenario was chosen as it seemed to most accurately describe most recent international developments, and for a global level, projection results are closest to the mean of all scenario results presented by the IPCC.[e] As aggregating mean values from data for all SSP scenarios or all global climate models contributing to the CMIP 6 working group would have exceeded the scope of this thesis, only data for one SSP scenario, obtained from one global climate model was used. Therefore, values visualized should be seen as indicative only, even though it can be expected that they would not differ significantly from projected mean values aggregated from all available data sets.

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g Fick and Hijmans (2017) 'WorldClim 2. New 1km spatial resolution climate surfaces for global land areas'.

Vegetation
The Tragedy of the Commons

Benedikt Mass

Traditionally, nature and vegetation have been of paramount importance to Ugandan societies, both as a material resource and as a source of livelihood. Even today, sourcing renewable materials from a commons for the production of household goods and building materials is a widespread, albeit often illegal strategy. Rising population numbers coupled with low purchasing power pose an imminent threat for overexploitation in a system that may once have been balanced. Environmental degradation and resource depletion are among the most pressing and most visible challenges that Uganda is currently facing.

Livelihoods and Food Crops

Naturally, geography and climate have a major influence on vegetation. Uganda's different vegetation zones, both natural and cultural, therefore correspond to the geographical and climatic regions already described. In the mountainous areas on the country's eastern and western boundaries, high altitude vegetation, with extensive pine tree forests and other cold-resistant plants can be found. Here, arabica coffee and tobacco are important cash crops, whereas potatoes, root vegetables and bananas constitute the staple diet. In the arid north, the vegetation is that of a dry savannah, with a mixture of grassland and open woodland consisting of acacia species and other drought-resistant trees and shrubs. While pastoralism is prevalent in the north of the country, land cultivation is practiced as well, with an annual cropping system of more drought-resistant crops – mostly sorghum, finger millet and groundnuts.[1]

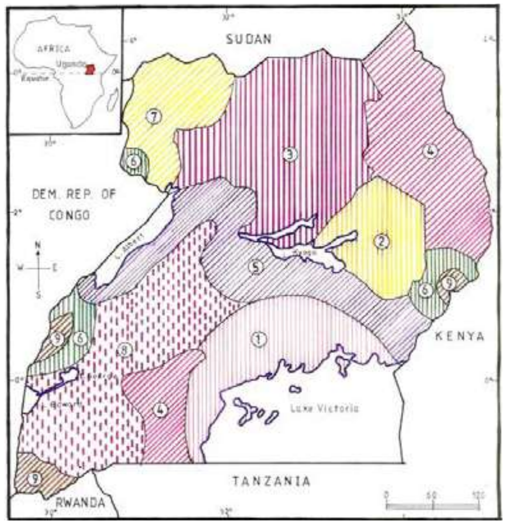


fig.1 Agricultural zones of Uganda. (1) Lakeshore intense banana, coffee; (2) Millet, cotton; (3) Northern annual Cropping and Cattle; (4) Pastoral, some annual crops; (5) Banana, Millet, Cotton; (6) Medium altitude banana,coffee; (7) West Nile annual cropping and cattle; (8) Western Banana, Coffee, Cattle; (9) Montane.

In the central and southern region, the variety of crops is considerably larger due to more favorable climatic conditions. Perennial crops like coffee and plantain trees are dominant food and cash crops, complemented with sweet potatoes, maize, cassava, beans and other leguminous plants. There are two main harvest periods following the rainy seasons, but the main food crops of cassava and matoke (plantain) are planted and harvested year-round.[2] Agriculture is most intense in the Lake Victoria area, often called the Lake Victoria Crescent, due to its shape following the shoreline from east to southwest. As population density decreases away from the lake's shores, so do agricultural intensity and demand for arable land. However, large scale-industrialized agriculture is still the exception rather than the rule in Uganda.

Patterns in the Central Region

Returning to Thomas[3] and the concept of the catena, the succession of different zones on a single hill like links in a chain, we will now take a closer look on the vegetation of the more densely populated Central Region. As already described in the first chapter, undulating hills dominate the topography of the area, spanning over the whole, vast expanse of this region. Like islands, they rise from the large network of seasonal wetlands and papyrus swamps on the valley floors, which are interconnected over large distances. A distinct vegetational pattern repeats on every hill with minor variations. The swampy areas with papyrus or reeds at the bottom are succeeded by a mixture of open grassland, shrubs and cultivated areas. Settlements are located towards the top of the hills, with most of the houses dispersed along the flatter areas, surrounded by kitchen gardens, banana plantations and fruit-bearing trees. Secondary open woodlands intersected by shrubs and cultivated areas, and small patches of close-canopied areas with larger trees on top of some of the steeper hills are the only remainders of large primary forests that occupied the area before humans started to interfere with the natural ecosystem on a large scale.

As we turn a bend in the road, a new view opens up. The papyrus swamp, first only visible as a small patch of high reeds to our right at the foot of the hill, suddenly stretches into the distance to both our sides, gradually disappearing into the morning mists on the horizon. A white cattle egret wades between the tufts of bent papyrus by the side of an almost rectangular waterhole – the remainder of some artisanal brickmaker extracting clay for his moulds. It preys on small amphibians or the larger of the many insects whose larvae develop in the murky waterbodies. The wetland ecosystem of papyrus sedge, with the thousand green rays of their inflorescence towering above our heads, provides a habitat for a multitude of species, from insects to birds and small mammals, and has been a material resource for human cultures for thousands of years.

Anthropogenic Influence

Thomas[4] shows that major parts of the natural vegetation in Uganda were already secondary, or at least altered by humans to a considerable degree, during the 1940s. With natural grasslands and woodlands increasingly converted into subsistence farmland and secondary vegetation (Fig.XY), there are observable effects on local ecosystems. These include loss of biodiversity, erosion and soil depletion due to over-intensive use and insufficient soil and water conservation measures.[5,6] As a consequence, agriculture has become even more vulnerable to the effects of climate change outlined in the previous chapter, especially with the introduction of non-native food and cash crops such as Arabica coffee and rice.

In traditional, pre-industrial societies, renewable resources were the primary, and sometimes only, material source. While many of these persist in vernacular contexts in Uganda, today the most widely used resource taken from natural environments is wood, both as a building material and as an energy source. In the first half of the 20th century, both Roscoe[7] and Thomas[8] had already commented on the visible effects of deforestation, announcing what has become the biggest anthropogenic threat for local ecosystems. The pressure of exploitation, which has existed since ancient times, rises with increasing population numbers. In his famous essay *The Tragedy of the Commons*[9], John Hardin describes the logic behind such dynamics as follows: over-extraction of a limited resource – economically logical from an individual's point of view – cannot be compensated by a public good or common asset like an ecosystem after a certain tipping-point is reached.

Between 2000 and 2017, a net loss of 47% of the country's forest area has been registered, predominantly on privately owned land.[10, 11] Even though industrial timber plantations – to which recent reforestation efforts are mostly confined – have been growing by 650% during the same time period, deforestation exceeds newly-gained tree cover by a factor of ten (fig.2).[12] Again, with an exponential population growth rate, deforestation and land use trends are unlikely to change in the foreseeable future,

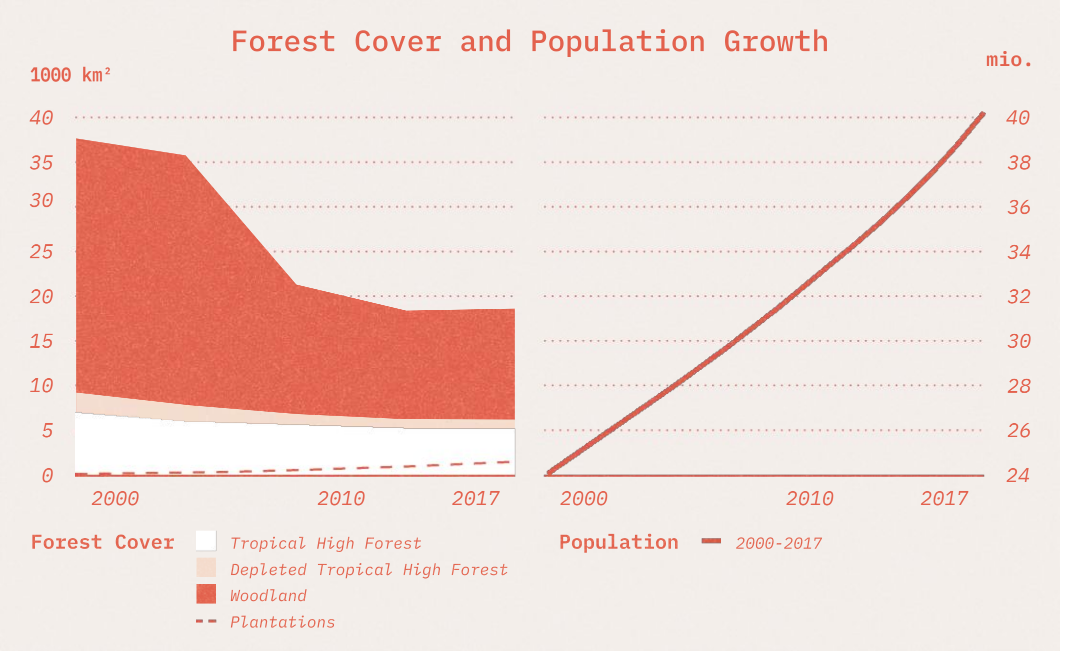


fig.2 Forest Cover and Population Growth in Uganda. With rising population numbers, forest cover descreased significantly.

if no counteractive measures are taken.[13] Van Soesbergen et al.[14] project an additional loss of up to 80% of forest cover until 2050, as compared to 2005. In addition to all other ecological implications, this would mean that a tipping point would be reached, where the previously wooded areas turn from a net carbon sink into a net carbon emission source.[15]

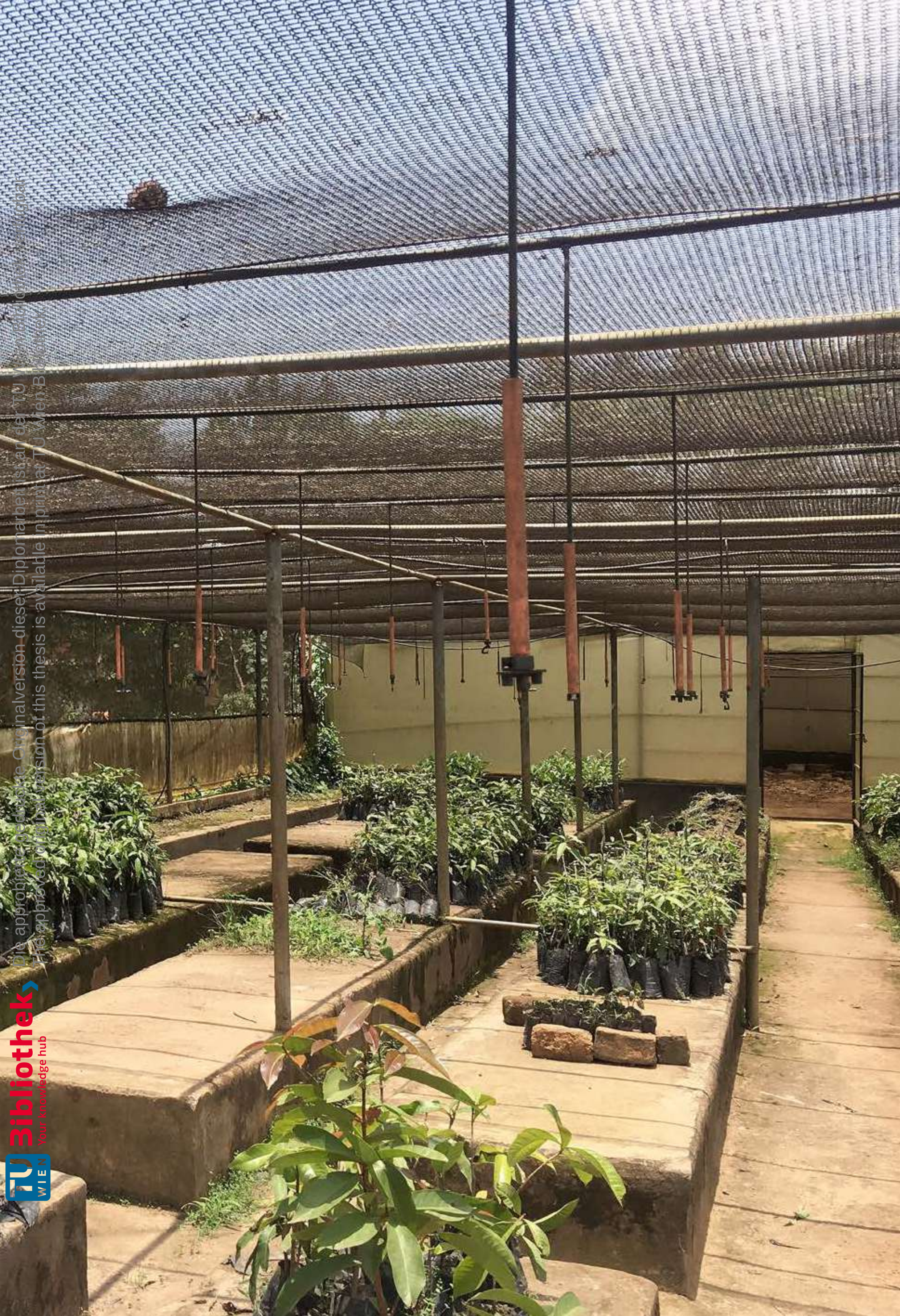
The main reason for deforestation is the demand for wood as an energy source, either as firewood or for charcoal production. 79% of total wood production is attributable to these uses, to the largest part as small-scale production to meet domestic energy demand. At the same time, sawn timber production amounts for only 5% of all wood production.[16] This means that, while timber use and provenience should still be taken into consideration, e.g., in building construction, using wood as and energy source is by far the most problematic issue.

Conservation and Reforestation

Facing the threat of total degradation of all woodlands, which would not only lead to an ecological but also to a severe energy crisis, several key measures have been identified and adopted by Ugandan policymakers to tackle the problem. Efforts toward mitigating the extent of deforestation follow two baseline approaches: conservation and reforestation. While a governmental target to restore forest areas of 2.5 million ha by 2030 has been formulated by the Ministry of Water and Environment[17], reforestation has so far mostly shown in form of industrial plantations for timber production.

Conservative measures include, but are not confined to, increased monitoring activities and law enforcement to crack down on illegal logging practices. Furthermore, they expand towards the root of the problem: the country's high domestic energy demand. Both providing clean energy sources like solar power or alternative fuel from commercial bio-energy plantations[18] as well as reducing energy demand by implementing more efficient charcoal-production techniques and cooking stoves[19] helps to alleviate pressure on remaining natural forests.

For timber trade, no functioning regulatory systems exist in Uganda, due to lack of institutional control and weak law enforcement on district level. Therefore, the largest part of the timber trade, estimated at 80%, is considered illegal.[20] The share of illegal logging activities on the other hand is hard to quantify, as



estimates for illegal trade also include timber sold without paying mandatory taxes, and timber produced without compliance to safety regulations, although it must be assumed that due to the largely informal nature of the Ugandan market, all these issues largely go hand in hand.

While timber production from plantations could not meet the demand in past years, leading to unsustainable harvesting practice in natural forests, yields from plantations will grow exponentially in the following years due to efforts taken under the Sawlog Production Grant Scheme (SPGS). Timber production will soon significantly exceed domestic demand, both alleviating pressure on natural forests and creating an income opportunity through exports to neighbouring countries facing similar issues.[21] The most common plantation trees are pine and eucalyptus species,[22] and while plantations as an alternative timber source help to conserve natural forests, they are not without environmental concerns. Eucalyptus and most pine species are not native to Uganda, and therefore of low ecosystem value. Monocultures are more susceptible to pest and disease, thus increasing the need for pesticides. Additionally, the water demand of eucalyptus is high, potentially lowering the groundwater table and requiring irrigation in less humid regions, thus increasing stress on water reserves in drought periods.

Sustainable Timber Production

More recently, indigenous species like musizi (maesopsis eminii) and, to a smaller extent, mvule (milicia excelsa) are therefore increasingly promoted due to their ecosystem value.[23] Mvule, subject to Thomas' comment on its increasing scarcity in primary woodland environments, is still an important timber source in Uganda. Its use as a shade tree in banana and coffee plantations, together with the popular belief that ancestral spirits gather under its crown,[24] may be protecting the few remaining ancient specimen in settlement areas. However, because the termite resistance of its wood makes it a valuable timber source, mvule has been extracted on a large scale and is thus listed as "near-threatened" on the IUCN

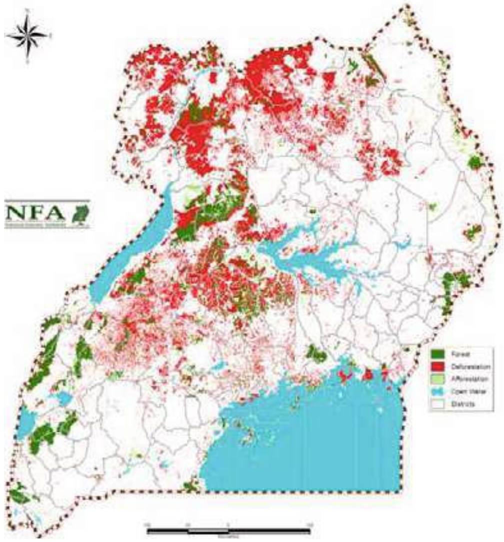


fig.3 (previous page) A nursery at the Kwanada Research Institute in Kampala.
fig.4 (above) Forests in Uganda. The dark green patches indicate forest area; light green patches are areas of afforestation and red patches represent areas of deforestation.

Red List of Threatened Species.[25] Regarding its promotion, it has been observed that the mvule tree does not perform well in plantation settings, due its susceptibility to pests in monocultures. In contrast, small-scale mixed-species plantations and sustainably managed forests under the administration of the National Forest Authority of Uganda, show that the Mvule tree thrives better in a diverse environment.[26]

Policymakers increasingly focus on the promotion of certified plantation forestry and agroforestry or woodlot cultivation as an additional means to significantly increase biomass from trees outside forests and woodlands. The two strategies address two different scales. At the large scale, the promotion of certified plantations aims to increase the sustainability of industrial timber production. Agroforestry and woodlot cultivation, are targeted at small-scale agriculture and subsistence farming. By planting trees among crops and on field margins as well as by establishing micro-plantations on fallow land, the aim is to meet both domestic wood and energy needs while increasing biodiversity in cultivated landscapes. At the same time, this may result in higher yields, as heat- and drought-sensitive crops thrive better under the shade of trees.[27]

As of 2023, four forestry companies in Uganda are FSC-certified for sustainable plantation management and code of conduct, with a plantation area of 43 000 ha.[28] There are no up-to-date statistics about the total area used for timber plantations. To put this number into perspective, however, in 2017, total plantation area was 160 000 ha.[29] As the area of timber plantations have been rapidly growing – with a growth rate of 750% from 2000 to 2017 – they can be expected to cover a considerably larger area of land by today, effectively lowering the percentual share of FSC-certified plantation timber. Additionally, the New Forests Company, Uganda's largest certification holder that manages almost 50% of FSC-certified plantation area, faced severe allegations of human rights violations through land grabbing and forceful eviction in 2010,[30] although to the authors' knowledge, no legal action seems to have taken place. This shows that there is significant room for improvement regarding sustainable timber production, even if important first steps have been taken.

Bamboo as a Sustainable Alternative

Given the implications connected to wood production, bamboo and other fast growing, local species, may provide a more favourable alternative to timber in general. While bamboo is already widely used for many applications from food production to building construction in the few areas where it grows naturally on a larger scale,[31] the bamboo industry in the country is largely underdeveloped.[32] Indigenous growth is restricted mainly to protected areas in the mountainous regions of the Rwenzoris and Mount Elgon, where highland bamboo (oldeania alpina) is estimated to grow over a total area of 533 km², and to Northern Uganda and the West Nile region, where lowland bamboo (xytenanthera abyssinica) grows in an estimated area of 108 km². [33] While wild bamboo stocks, like other forests in the country, are severely degraded due to illegal overharvesting and unsustainable management, common bamboo (bambusa vulgaris) and giant bamboo (dendrocalamus giganteus) have been naturalized and are grown in farms and household lots all over the country.[34]

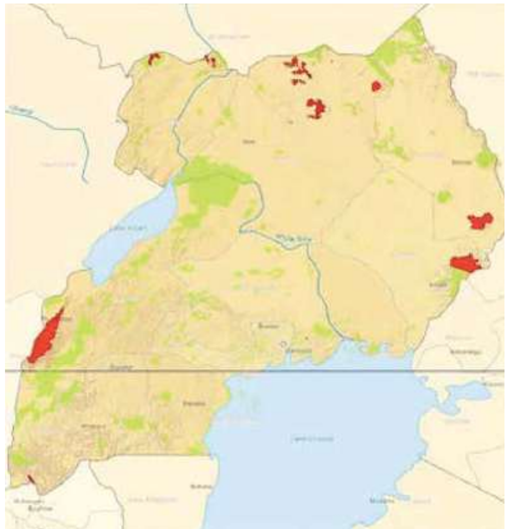


fig.5 Bamboo in Uganda. The light green patches represent protected areas; red indicates the location of areas with indigenous bamboo growth in Uganda.

The country now implemented a ten-year National Bamboo Strategy and Action Plan[35] which aims to develop a large market for bamboo, restore depleted natural forests and establish 263,000 ha of bamboo plantations on private land through training and financial incentives. In addition, in line with the approach to increasing tree biomass, the planting of bamboo is encouraged in smallholder agriculture, along farm boundaries, as a shelterbelt on steep slopes and around water bodies to improve watershed management.

Because of its versatility in use and its rapid growth, bamboo has a great short- and medium-term potential. As a timber alternative as well as a biomass input resource for charcoal production, it can help to rapidly reduce the pressure on natural forests as well as the environmental footprint of the building industry, if the right external conditions are enforced by policymakers as proposed in the conducted studies and development strategies.[36]

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23 Sawlog Production Grant Scheme (2009) *Tree Planting Guidelines for Uganda*. Kampala: SPGS.

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People
Cultural Diversity and the
Baganda

Maximilian Weidacher

To subsume the tribes and kingdoms that fell in their newly announced Uganda Protectorate, British officials adopted the term Uganda in the late-19th century. Adopted, as the word Uganda was no British invention but borrowed from Swahili where it was used to speak of the country of the notoriously well-organized and formerly dominant kingdom of Buganda.[1] The arrival of the British in East Africa marks a momentous point in history, for it defines a "before" and an "after". What we today call Uganda was once a heterogeneous region of rival tribes and kingdoms. Against this background the terms Uganda and Ugandans represent the consolidation of power relations within the region, and carry with them the notion of disproportionate marginalisation.

55 Tribes

From an ethno-linguistic perspective, the tribes living in Uganda can be grouped into a Bantu-speaking majority, who occupy the central, southern and western parts of the country and a non-Bantu-speaking minority who live in the eastern, northern and north-western regions of the country. The non-Bantu-speaking minority consists of Nilotic, Central Sudanic and Kuliak peoples.[2] Archaeologists suppose that around 3000 years ago Bantu-speaking tribes entered the inter-lacustrine region from the south-west, while Nilotic speakers arrived more or less simultaneously from the north-east. Both Bantu and Nilotic conquered the Central Sudanic and Kuliak peoples, who had settled there long before their arrival, only to continue waging wars on each other. Most of the Central Sudanic and Kuliak speakers were assimilated into Bantu-speaking cultures but continued to exist in small numbers within Nilotic territories. In opposition to the generalizing term 'Ugandans', the map on the right allocates 38 of the 55 tribes that live in the country today. The districts with a predominantly Baganda population are indicated by the large purple area which also roughly coincides with the Central Region of Uganda.

The 15th century was a turning point in tribal history. In the Bantu-speaking and mainly agricultural south, kingdoms began to form, while in the Nilotic north, people remained organized in smaller nomadic or pastoral tribes. The division that separates these tribal groups and their cultures to this day, the Bantu-line, stretches across the entire African continent. In the case of Uganda, the ethno-linguistic boundaries coincide with natural boundaries such as the lakes and rivers of the inter-lacustrine region. In the introduction to their book *Tribal Crafts of Uganda* published in 1953, Margreth Trowell and Philipp Wachsmann note that "There is little cultural cohesion between the various tribes included within the country's artificial boundaries (…)" and continue that "even within the confined Bantu region of Uganda there is as much radical and cultural diversity between the different Bantu-speaking tribes as may be found between any of them and the speakers of non-Bantu languages in the northern half

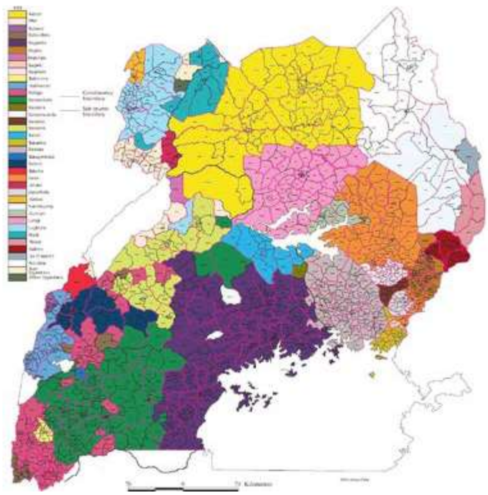

fig.1 Distribution of tribal groups in Uganda (2002 census).

of the Protectorate."[3] Through the description of the material and immaterial products of 34 tribes it becomes evident that the controlling factor in the lives of the people is a very plain one: geography. For it is primarily the "physical conditions such as rainfall, altitude, proximity to forest, lake or grassland will decide whether the land shall be occupied by a hunting or fishing community, by pastoralist or agriculturalist (…)."[4] In formulating the hypothesis of the Three Staple Diets, the survey takes a surprising turn that is worth mentioning. Trowell and Wachsmann claim that opposed to the ethno-linguistic classifications applied above, the whole way of life of a tribe lies in the contents of its food-pot, and that there are three division that cut across all tribal groupings: grain, plantains and milk.

At the construction site we once had a discussion on food. We had noticed that workers were eating the same dish almost every day, sometimes even twice a day. The meal consisted of a mash from maize flour called Posho accompanied by a mildly seasoned bean-stew. As much as we were analysing their diet, which was peculiar to us, they were amused by ours. To the workers it was surprising to see why anyone would choose to eat chapati and fruit for lunch. They told us that fruit are not considered to be food and that to them only few dishes are worth to be called a meal. Among these: Posho, manioc also known as cassava, beans and of course the plantain called Matooke.

The Baganda

At the turn of the 20th century, British scholar John Roscoe spent 25 years in an Anglican mission in East Africa. In his writings, which are among the oldest documents on Ugandan ethnography, he describes the Baganda kingdom as culturally superior compared to their neighbors. According to Roscoe, the Baganda were more careful about their personal appearance, their homes were neater and tidier, their manners courteous.[5] Roscoe's book *The Baganda: An Account of Their Native Customs and Beliefs*, published in 1911, reads like the vision of a fantastic bucolic utopia. "The kingdom of Uganda may be described as hilly (…). The land is well watered, and every depression contains a swamp or a river (…). The Baganda lay out their gardens on the sides of hills and seldom descend to the lower parts of the valleys, except when there is a long period of drought and they seek moist land for their sweet potatoes (…). Plantains cover large areas of land (…). The rainfall is plentiful (…)."[6] In regard to labor and agricultural practices, Roscoe noted that bananas grow so freely that Baganda women can feed their families with a minimum of labor. Since the plants bear the whole year round, there was no need for them to store food. According to Roscoe, while no one ever went hungry and real poverty did not exist, the Ganda people showed no inclination to hoard wealth. When compared to their close neighbors, who subsisted on cereals, the egalitarian cultural traits of the Baganda are much closer to those of foraging societies. Continuing this line of thought, Trowell and Wachsmann judge the material culture of the Baganda to be far less sophisticated than that of grain-eaters or pastoral societies. They argue since plantains cannot be stored but must be freshly cut from day to day, no granaries or out-buildings, no great collection of storage baskets, no jars and other special artifacts are necessary. Hence, the material culture of plantain cultivators is rather rudimentary.[7] Nevertheless, abundant availability of a reliable and nutritious crop most likely reduced the amount of stress as well as time and effort required to provide food, which in return allowed time for the development of sophisticated hierarchies with an underlying well-structured administration.

The Baganda society was divided into two classes – a ruling class and free peasants. While the "despotic powers"[8] of the Kabaka, the king of the Baganda, were passed on in a patrilineal hereditary system, chieftaincy of the tribes followed meritocratic principles. The patriarchal

fig.2 "Carrying the King and his Brother"; a ceremony documented by John Roscoe.
fig.3 (next page) A street with various shops in Wobulenzi.

hierarchy extended over all levels of society, from the tribes to clans and individual families. Descent is patrilineal throughout society, with each child belonging to the father's clan and a woman becoming a member of her husband's clan upon marriage. To this day, kinship and descent are important to the Baganda, and there appears to be a high degree of solidarity within the clans, as well as a deep respect for traditional hierarchies. In everyday conversation, we found that all men are referred to as brothers and all women as sisters. In addition to one's genetic next of kin, we were told that anybody from an older generation is considered an uncle or aunt.

The royal family as well as the chiefs and their families lived in the fortified royal enclosure. Situated on one of the hills of present-day Kampala, the royal enclosure formed the sole center of power and administration in the kingdom. The country itself was divided into large districts separated by natural boundaries such as rivers or swamps, with each district being home to a particular clan. The district-chiefs were responsible for governing their district and keeping the estates in good order as they belonged to the kingdom. This included structural tasks such as the establishment of a country seat, from which the districts were controlled, or the construction and maintenance of roads and bridges, as well as administrative tasks like the appointment of sub-district-chiefs or the annual collection of taxes. This centralized structure of governance may in part explain the primacy of Kampala in modern times regarding size, infrastructure, economic potential and political dominance.

Under a tenure system, peasants were given a plot of land by a chief in return for certain duties. While men spent most of their time providing food or precious banana beer for their chiefs, participating in communal construction and maintenance work or paying annual taxes, it was the women's job to tend the garden. As in most patriarchal societies women were responsible for most of the domestic and care work such as collecting firewood, carrying water from the well, cooking and raising the children - unless a man was wealthy enough to have slaves or servants.[9]


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fig.4 Inauguration of A. Milton Obote as president in 1962.

Under Foreign Rule

Slavery serves as a keyword to move on to another period in history. The collection of slaves was a practical side effect of the Baganda's successful warfare against neighbouring tribes, for slaves, ivory and cowry shells were among the most valuable commodities. At the beginning of the 19th century, traders from the Arabic world were the first foreigners to arrive in East Africa. They were not so much interested in cowry shells, but they had set out in search for slaves and ivory, and soon a dense network of trade was established between foreigners and the inhabitants of the interlacustrine region.[10]

Not much later, in the 1860s, the British arrived at the shores of the largest lake in the region, soon to be named after the Queen of the Empire, Victoria. The British had similar interests to the Arab traders and negotiated an economic treaty with the Buganda kingdom. In 1884, the Protectorate of Uganda was proclaimed, which, at least by definition, guaranteed a degree of self-government, as opposed to colonial rule. Further treaties with other kingdoms extended the borders of the protectorate to an area roughly equivalent to present-day Uganda.[11] The consequences of this initially bilateral agreement for the rest of the country were discussed earlier in this chapter.

The consequences for the broader region can be summarized as a cultural transformation due to Western influence. As this is a vast topic in itself, we can only touch on certain aspects of it in the following chapters on the built environment. For now, there is only room to mention three keywords that are directly linked to the period of the Protectorate of Uganda: the construction of the Uganda Railway from Mombasa to Kampala, the introduction of the concept of cash crops (tea, cotton and coffee) and the somewhat forceful attempt to replace natural religions with Christianity.[12]

Independence

When Uganda gained independence in 1962, subdued tribal rivalries boiled over. In the power vacuum left behind by the British, the first democratic elections were held. The king of Buganda, Mutesa II, was elected president and A. Milton Obote became the country's first Prime Minister. What followed were two decades of political instability and unrest. Obote ousted Mutesa II and established an oppressive one-party system. In 1970, Idi Amin seized power in a military coup and began his reign of terror. In 1978, with the help of rebel federations, Obote overthrew Amin and resumed his rule, only to surpass his predecessor in brutality.[13]

The rise to power of former insurgent force leader Yoweri Museveni in 1986 finally put an end to Uganda's bloody debut in the post-independence era. Under Museveni, Uganda's government has succeeded in eliminating violent tribal conflict while promoting political liberation and economic reform. In 1995, following the promulgation of the country's current constitution, almost all the traditional kingdoms were symbolically restored, with the monarchs' power limited to cultural matters. Throughout the country, ethnicity and clan affiliation are important factors in individual identity, social position and self-perception - with the Baganda remaining the dominant ethnic group. In 1996, in the country's first democratic presidential elections after independence, Museveni, himself a Hema, not a Baganda, was elected president and has been re-elected ever since.[14]

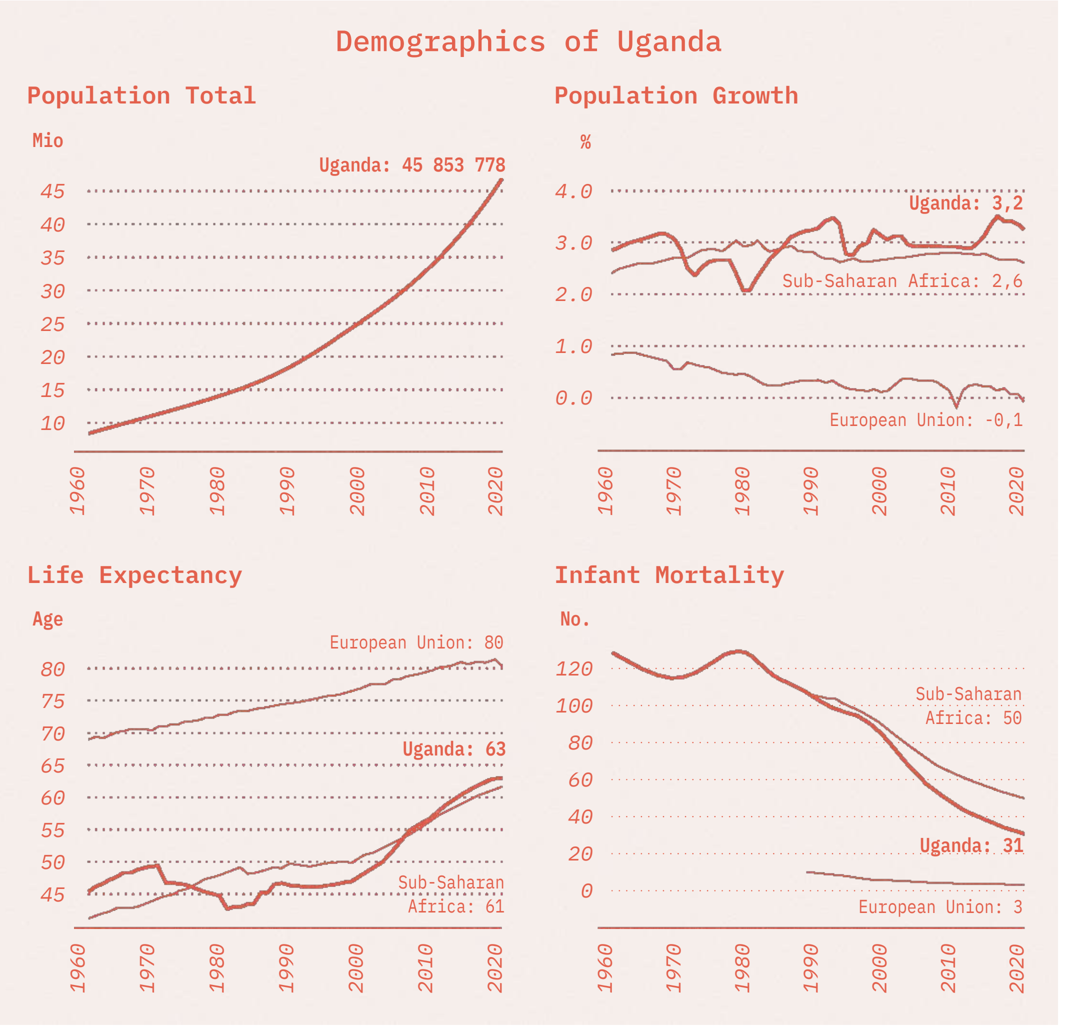

fig.5 Demographics of Uganda. From top left to bottom right: Total population of Uganda; Population growth (annual %); Life expectancy at birth, total (years); Mortality rate, infant (per 1000live births).

Growth

Having arrived at the relative political stability of present-day Uganda, we will move from a mode of qualitative description to quantitative measurement. In the following paragraphs, we try to capture the current state of the country from a demographic point of view, comparing figures and trends to neighboring countries as well as with the European Union. Looking at Uganda's population we see a young and rapidly growing country. Today's population of 47 million inhabitants[15] is expected to double by 2050. After Nigeria, the inter-lacustrine region is the most densely populated area in Africa. The country's average age of 16 years and a balanced population pyramid constitute good preconditions for a high population growth rate. Despite the decline since 2017, Uganda has a higher population growth rate of 3.2 percent compared to 2.6 per cent for sub-Saharan Africa.[16]

From a demographic point of view, there are two main factors to evaluate the physical well-being of a society: life expectancy and infant mortality. While life expectancy has continuously increased in Uganda in the first decade of independence, the years of political unrest and tribal rivalries left a visible dent in the statistics. Reaching an absolute low point in the 1980s, numbers are steadily rising again. Dying at an age of 63, the average Ugandan lives striking 20 years less than the average citizen of the European Union.[17] With the 1980s as a turning point, statistics on infant mortality show a similar picture. The number of deaths per 1000 live births have fallen steadily from 130 in 1980 to 32 in 2020. Although a third lower than the median in sub-Saharan Africa, it is still ten times higher than in the EU.[18]

Many of Uganda's neighboring countries are still marked by political unrest and conflict, first and foremost South Sudan and the Democratic Republic of Congo. In 2020, 2,7% of Uganda's population were refugees or asylum seekers - figures that reflect the country's geopolitical role in East Africa. This 2,7% equates to around 1,4 million people, making Uganda the country with the highest number of refugees in Africa.[19] Looking at migration within Africa we have come full circle in this chapter, as the high proportion of people with a migrant background adds to the country's already diverse culture. However, hovering above and common to industrialized countries all around the world, Uganda is confronted with another distinction of increasing importance: the divide between rural and urban populations.

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City and Countryside
The Rural-Urban Divide

Maximilian Weidacher

While at the beginning of the 20th century urban growth took place primarily in the countries of the Global North, it is currently the rapidly developing countries of the Global South that have the highest rates of urbanisation.[1] Rapidly growing cities in the Global South are under double pressure, with migration from rural areas on one hand, and high natural population growth in the cities themselves on the other. Particularly countries in East Africa with low levels of urbanisation have above-average urbanisation rates. First and foremost, Uganda: at an average urbanisation rate of 5.4%, the country's urban population has doubled in just 12 years.[2]

Cities in Uganda

The example of Uganda illustrates a phenomenon common to many African countries. Prior to the establishment of the Uganda Protectorate under British imperial rule, the only population concentrations that could be characterized as urban were the royal capitals of the pre-colonial kingdoms: Kampala for the Baganda and the smaller ones of Bunyoro, Ankolo, Toro and Busaoga tribes. At that time, there was already a division between the rural and the urban, but it was not of a competitive nature. The urban domain was primarily power and administration; the rural domain was exclusively agricultural production.

fig.1 "A Road in the Capital"; documented by John Roscoe.

Under the strong economic imperative of the British Protectorate, Kampala's role shifted from a place of power and administration to a place of power, administration and commerce. The introduction of Western economy opened Kampala and smaller towns to new residents, thus initiating urbanisation.

A century later, the Ministry of Lands, Housing and Urban Development presents urban growth as a key factor in the country's development. Acknowledging the persisting primacy of Kampala, the latest edition of Uganda's National Urban Policy (2021) sets out a strategy to address the imbalanced condition.[3] In order to distribute the currently concentrated urban growth more evenly across the country, four additional regional cities, namely Gulu, Mbale, Mbarara and Arua, as well as five strategic cities – Hoima (oil), Nakasongola (industrial), Fort Portal (tourism), Moroto (mining) and Jinja (industrial) – are to be developed.[4]

While towns and urban agglomerations are growing all over the country, Kampala and its Greater Metropolitan Area (GKMA) remains the only urban center in Uganda. Figures illustrate the imbalance: of the 25% of the country's urban population, more than half live in Kampala. 75% of Ugandans live in rural areas, which roughly corresponds to the 70% of Ugandans employed in the agricultural sector. Of the remaining 30% working in industry and services, only 3% are in formal employment. However, if we compare the sectoral distribution of employment with the proportional distribution of national economic output, a reverse picture emerges. While 60% of GDP is generated in the GKMA (and another 10% in other urban areas), the share of the agricultural sector is only 20%.[5] As Uganda is seeking a sectoral transformation from an agricultural society to a service society, analysis on the transformation of Uganda's economy conducted by Mukwaya and his colleagues at Makere University, Kampala, show that "the shift in sources of wealth in the economy is not being accompanied by a shift in employment out of agriculture to other sectors". Rather the opposite is the case: the employment rates in the agricultural sector are increasing, while it's contribution to economy is declining.[6]

The GKMA

Today some 3,6 million people live in the Greater Kampala Metropolitan Area.[7] As with the name of the country, the essence of a grievance lies in the label itself: Greater Metropolitan Area. For Kampala, as for most other capitals in sub-Saharan Africa, urban sprawl has become the main challenge, with other challenges being often just a consequence of rapid and uncontrolled expansion. The series of aerial photographs of the Greater Kampala Metropolitan Area illustrates the degree of horizontal expansion of the city over time.

A key problem is that planning authorities are often unable to keep up with the pace of exponential urban growth. As Kampala grows, more and more land unsuitable for human habitation is being built on. The resulting sealing of the land has a negative impact on water run-off, which in turn increases the risk of ground erosion.[8] Ecological burdens and pollution resulting from inadequate sanitation and waste management primarily affect the already disadvantaged and marginalised population; inner-city industrial areas contribute to further air and water pollution. Moving on to transport and mobility, as the economic center of the country, Kampala is also the main transport hub. Since there is no active railway network in Uganda, all freight transport is by road and most of the heavy traffic routes go to or through Kampala. Although a bypass was opened in 2009, the road network in Kampala itself has no hierarchical structure, which

fig.2 The GKMA in 1985 (top) and 2020 (bottom).
fig.3 (next page) Motorcycle transporting plantains.

aggravates traffic problems. In the absence of public transport, mobility in the city relies on private minibuses and individual transport. As a result of horizontal expansion, distances within the city are also increasing, with people spending up to three hours commuting between home and work.[9] As wealth increases through rising GDP per capita, so does motorised transport. All these factors result in increased traffic congestion, which in turn leads to higher emissions of both fumes and noise. In Kampala, as in other urban areas in Uganda, most of the urban poor live in slums. The informality of settlements generally comprises a lack of infrastructure such as electricity, water supply or sanitation as well as the absence of legal security. In a report on cities and growth in Uganda published by the GEZ in 2019, Schweizer-Ehrler wrote that "attempts to create adequate housing in the past often led to the displacement of informal settlements to even less favorable areas, while the newly created housing was occupied by people with higher incomes."[10] Figures show that the number of people living in slums in Uganda has fallen significantly in recent decades, but it is estimated that 54% of the country's urban population are still living in these informal settlements.[11]

Despite the uncertainties and hardships of urban life, people from rural areas are drawn to the metropolis. Rather than providing answers, the urban condition of the Greater Kampala Metropolitan Area raises further questions about what motivates people to change their rural lives for a life in the city.

The Rural-Urban Divide

As early as 1973, British economist E.F. Schuhmacher commented on the consequences of a rural-urban divide in the economies of developing countries. He pointed out that if development efforts continued to be concentrated mainly in the big cities, the competition of the industries created would proceed to disrupt and destroy the already sparse non-agricultural production in the rest of a given country. Schuhmacher predicted that the urban bias would cause additional unemployment in the countryside, thus accelerating the migration of the destitute into cities most likely incapable of absorbing them - a prediction that came true in the following decades of progressive rural out-migration.[12] In a more recent study on the rural-urban transformation in Uganda, Mukwaya and his colleagues confirm Schuhmacher's predictions, pointing out that „persistent inequalities that exist between rural and urban areas show in low poverty reduction rates in rural areas despite economic growth at national level. At the level of the household, poverty is strongly related to rural residence. (…) The majority of food-insecure people reside in rural areas."[6] And while a prosperous city life is far from certain for most rural migrants in Uganda, the chances of improving general living conditions in urban centers through formal or, as in most cases, informal employment are still higher compared to life in the countryside. It seems that it is not the urban pull factors that attract the rural population, but rather the sum of the rural push factors that are responsible for the exodus.

Countryside Life

As we turn to the fringes of the Greater Kampala Metropolitan area, we find an urban carpet blending into an even bigger carpet of lush green hills intersected by rivers and swamplands. Here "the peasants in the country lived in their gardens or plantations. These gardens were often joined one to the other, and a number of people lived in a community, often forming four or five miles of continuous garden with families living each on their own plot; the boundaries were vague merely defined by a gutter or a shrub here and there. These communities were the nearest approach to village life such as we know it."[13] At first glance and apart from the tone in language, John Roscoe's 100-year-old description of the countryside in the former Baganda kingdom still seems up to date. Despite the cultural differences of underlying agricultural practices discussed in the previous chapter, most of Uganda remains characterized by the scattered settlements of small-scale subsistence farming[14]. Compared to the transformation taking place in urban areas, the countryside and its farming population appear almost static. At second glance, however, looking at the countryside from within, we find change, yet at a different pace.

Patrick is 35 years old, like me. Most of his living he makes as a motorcycle-taxi driver, known as Boda or Boda-Boda in Uganda. Patrick and his friend and colleague Moses pick us up from the hotel every day and drive us to the construction site at Kimwanyi. All it takes is a short text message at night and the next morning they are there. The drive takes about 30 minutes – plenty of *time to ask a lot of questions. For both of us. Patrick comes from a farming family. His mother works in the fields, providing some of the food the family needs. What they don't eat themselves, they sell. He tells me that he also works in their garden when there is a lot of work to be done, like just before the rainy season when they have to prepare the ground and plant. When he is not a driver, he is a farmer, he explains, but most of the time he is a driver.*

In many ways, Patrick represents a growing number of Uganda's rural population. Categorized as small-scale subsistence farmers, most households are in fact no longer able to make a living from agriculture alone. Like Patrick, who moved to the outskirts of Wobulenzi in search of a reliable second income, many Ugandans migrate to urban areas, while their families stay behind. Rural-urban migration is only a partial exodus and although more and more people are moving from rural to urban areas, rural settlements are growing as well. Increased demand for land does not only lead to the depletion of natural resources but has resulted in a reduction of the area of arable land owned per farming household. In addition, land tenure under customary land administration is becoming increasingly insecure.[15] For families who depend on agriculture for their livelihoods, shrinking plot sizes translate directly into economic pressure at the household level.

Most farmers in Uganda engage in diversified farming and to some extent in market activities. A common pattern for farming households is to sell some of their produce just after harvest to meet the immediate household cash needs such as school fees, mobile phone credit or debt repayments. As their food stock reduces towards the end of a crop cycle, farmers usually return to the markets, this time as buyers instead of sellers.[16] The Uganda National Household Survey found that on average, only half of the food consumed by rural households came from their own agricultural production.[17] At the same time, the sale of agricultural products accounts for less than 50 per cent of their income. Low economic yields of Uganda's smallholder farmers are the consequence of a threefold problem. Firstly, Ugandan small-scale agricultural practices, like most non-industrialised agriculture, are low-yielding by nature. Secondly, limited market access and a lack of price information forces many farmers to sell much of their crop to middlemen at below-market prices. And thirdly, by selling crop rather than agricultural commodities, farmers miss out on the revenue of potential value addition. With ever-increasing monthly household expenses, there is a growing need for secondary employment in the countryside.

Rural-Out Migration

A qualitative study carried out in the Ankole district in 2021[18], identifies three main push factors for rural out-migration. First and most importantly, the study lists economic reasons. 90% of the people surveyed said that urban areas offer more job opportunities and higher wages. In terms of income, another frequently mentioned aspect was the limitation of arable land. 70% of respondents said that the lack of access to social infrastructure such as schools, hospitals, and housing was a reason for migration. Summarised as physical reasons, 60% claimed that "most of the communities' natural resources, including farmland, swamps, forests and (…) river catchments, were degraded and could no longer sustainably support their natural-resource-dependent livelihoods."[19] Wealthier households with educated and (semi-)skilled members were more likely to have out-migrants than poorer households, located in remote rural areas. Accordingly, households with out-migrant family members were mostly located in areas with good road networks and always in proximity to sub-regional urban centres.[20]

When asked about the preferred destination places, a surprising majority of respondents said that they would prefer the nearest municipal city over Kampala. Asserting the rural-out migration as primarily a matter of livelihood,

fig.4 (previous page) Motorcycle transporting plantains.

a possible way out of the current rural-urban divide in Uganda would be a shift from a centralised towards a decentralised urbanisation strategy. Development concepts that treat rural and urban areas equally would lead directly to a reduction of the pressure on existing cities and especially on the Greater Kampala Metropolitan Area. At the same time, the development of regional centers or secondary towns, would reduce the extent of socially disruptive long-distance migration. Looking at aspects of the divide at household level, improved living conditions for farming families can only be achieved through better access to infrastructure that provides basic social services such as healthcare, education, clean water, electricity, transport and communication.[21] As a counterproposal to non-agricultural employment, Schuhmacher advocates the creation of an agro-industrial structure in rural and small-town areas.[22] In his view, what matters in countries with high population numbers and a low degree of industrialisation, is not efficiency or output per person, but maximising the employment opportunities of the un- and underemployed. The promotion of labor-intensive small-scale production would distribute income opportunities both geographically and evenly among all members of society.

"An unemployed man is a desperate man, and he is practically forced into migration. This is another justification for the assertion that the provision of work opportunities is the primary need and should be the primary objective of economic planning. Without it, the drift of people into the large cities cannot be mitigated, let alone halted."[23]

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15 Mukwaya et al. (2012) 'Rural-Urban Transformation in Uganda', p.20.
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17 Ibid.
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On Buildings
Three Kinds of Vernacular

Maximilian Weidacher

While, to a certain degree, the diverse building traditions of Uganda's ethnic groups appear to be well documented, records of the country's recent architectural history are conspicuously sparse compared to other African countries. From a distance, a contemporary architectural discourse in Uganda appears to be almost non-existent. In this chapter, which is the introduction to our study of the architecture of the Baganda and the evolution of building culture in the Central Region, we want to explore this initial observation and develop an understanding of the relationship between tradition, modernity and the present.

Architecture and (In)Equality

The cultural diversity outlined in the previous chapters is also reflected in the diversity of Ugandan historical building styles. In line with Trowell and Wachsmann's theory of the Three Staple Diets[1], the different ways of subsistence and the underlying social structures and values can be read directly from the settlement structures and buildings. In all parts of Uganda, traditional building typologies and techniques seem to be disappearing, however not to the same extent. In order to better frame the transformations and changes of vernacular architecture in the Central Region, we will first discuss the phenomenon of unequal disappearance.

Another indication of the egalitarian culture of the ancient Baganda was their traditional architecture and the crafts and customs related to it. Despite the well defined hierarchical social structure, there used to be only one type of traditional building among the Baganda: the Kiganda. According to John Roscoe, both a chief's and a peasant's dwelling were based on the same pattern, the only difference between the two being the size of the dwelling and the care taken in its construction, the former being built by professionals and the latter by the inhabitants themselves.[2] Of the architecture of the ruling class, Trowell and Wachsmann write: "The most elaborate and highly developed buildings in Uganda were undoubtedly those of the chiefs of the Buganda Kingdom", and continue: "but unfortunately it is the Buganda Kingdom, which has had the most concentrated contact with western civilisation and has thereby lost so much of its own culture."[3]

fig.1 Homesteads along a village road near Nakaseke, Central Uganda.

A comparison of recent aerial photographs of rural areas of Uganda confirms that what was true 70 years ago holds true today. While in the north and east of the country traditional building styles can still be found, both morphologically and in terms of the materials used (see next page, fig. 2 and 3), in the former kingdom of the Baganda the traditional housing typology, the Kiganda, has completely disappeared or transformed (fig. 1) – despite all its elaboration. As unfortunate as the loss of the Baganda's unique way of building may be in many ways, it is also indicative of the country's perpetual state of inequality.

fig.2 (above) Acholi village near Gulu, Northern Uganda.
fig.3 Iteso Homesteads near Soroti, Eastern Uganda.

The End of the Ephemeral

In the lecture *Advocating for Architecture in Kampala*[4], architect Doreen Adengo says that permanent structures did not exist in the Buganda Kingdom in pre-colonial times. The materials used were thatch, wood, reed and earth. Even the Kabaka's palace, the Lubiri, was not built to last forever. Hand in hand with the introduction of new, industrialised building materials such as fired brick, cement or steel, the British colonial rulers erected the first multi-storey buildings in Uganda's towns and urban centres, soon to replace traditional building techniques. First and foremost, the Kabaka exchanged the traditional Lubiri for a new palace in historicist colonial style, thus making an unambiguous statement.

While most studies of Baganda vernacular architecture refer to the traditional, ephemeral circular buildings, Kikule and Jupe in Paul Oliver's *Encyclopedia of Vernacular Architecture of the World* describe a completely different form of construction, which in a sense represents a transient intermediate state. Both the adapted lifestyle and the dwelling itself strongly reflect the European influence within the ethnic group, the authors argue, citing that since the 1940s, the traditional building style has been gradually replaced by "a dwelling of square form and pitched roof approximately 7 m x 7m"[5].

Kikule and Jupe conclude "This housetype is widely seen in rural Baganda but has been almost totally replaced by a more modern equivalent in Kampala and along main roads leading to the capital city. Construction in these urban and semi-urban areas usually consists of buildings made of burnt brick walls, concrete frames, sawn timber roofs and corrugated metal sheeting."[6] However, it would be some time before the new building materials were also available in rural areas and, above all, affordable to the population.

The Promise of Modernity

In the wake of the Second World War, modernism found its way to Uganda in the late 1940s with the emigration of leftist thinkers and architects from Europe. In an essay on contemporary architecture in East Africa, Killian Doherty writes that from the mid to late 20th century, the former colonies were considered fertile ground for the continued flourishing of tropical modernist architecture. "This cautiously reworked modernism fueled the aspirations of the decolonised states, which also wanted to be counted among the countries of the "First World" and pointed to a superiority of Western architectural methods (...)"[7], says Doherty. Through the construction of new types of institutional and national buildings, modern architecture became an unmistakable symbol of general progress. In the case of Uganda, however, long years of political instability brought the modernisation

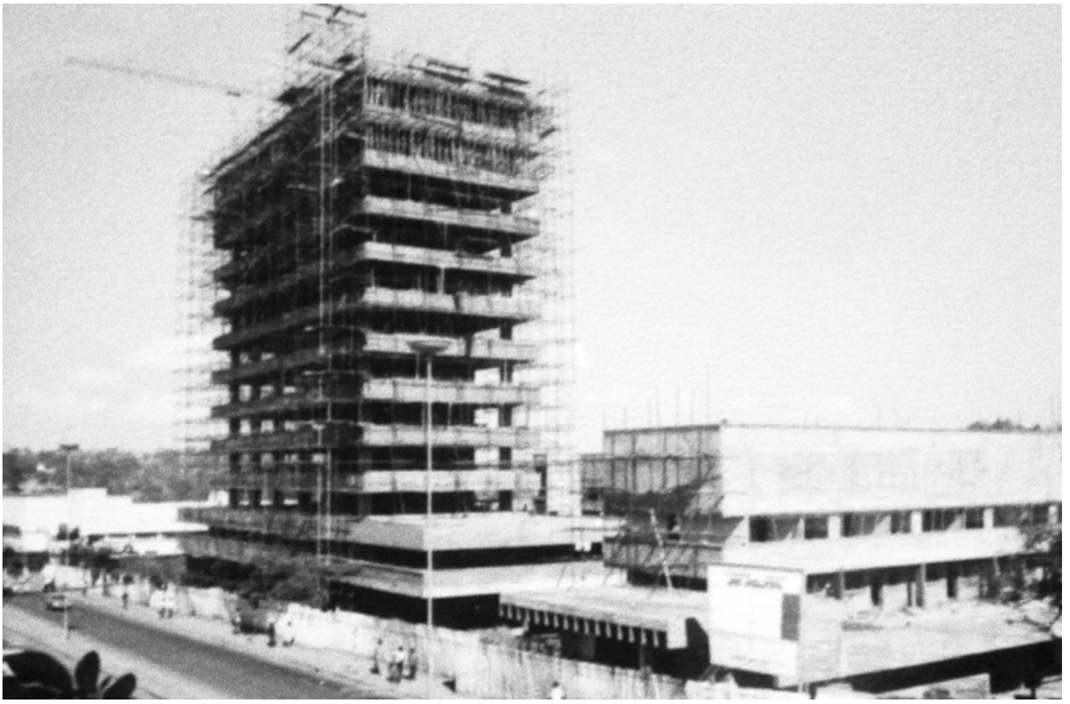

fig.4 Photograph of the construction of one of the country's few modernist buildings: The Uganda Peoples Congress Headquarters in Kampala (around 1970).
fig.5 (next page) A house of a presumably wealthy family; the degree of completion represents the ideal condition.

of the state to an abrupt end, and with it the formation of modern architecture. Despite or perhaps exactly because of this, Doherty goes on to comment that the example of the renewal of East African cities shows "that modernity is still celebrated as a panacea" - a perspective that can be applied to both neo-liberal urban visions and projects in the field of humanitarian aid and development.[8]

Architecture Without Architects

An early counter-proposal to universal narratives of linear (architectural) development and progress was the exhibition *Architecture without Architects* by Bernhard Rudofsky at the Museum of Modern Art, New York in 1964. In the foreword to the exhibition catalogue and the subsequent publication of the same name, Rudofsky situates his work within the hitherto historiography of architecture as follows: "Architecture Without Architects attempts to break down our narrow concepts of the art of building by introducing the unfamiliar world of non-pedigreed architecture. It is so little known that we don't even have a name for it. For want of a generic label, we shall call it vernacular, anonymous, spontaneous, indigenous, rural, as the case may be."[9]

Rudofksy describes this type of architecture, which evolved over centuries through immediate use and in absence of formally trained experts as „nearly immutable, indeed, unimprovable, since it serves it's purpose to perfection."[10] In view of the deep cultural entrenchment and alleged timelessness of vernacular architecture, Rudofksy asks whether it is still appropriate for architects to draw meaning and inspiration exclusively from what he calls "noble architecture".

While traditional building forms across the globe continue to be at risk, and are probably more endangered than they ever were before, today the value of vernacular architecture seems to be generally recognized, at least in an academic context. However, in contradiction to the original meaning of the term 'vernacular', Rudofsky's idealised image of a concluded cultural product has manifested itself in a misleading temporal restriction that ascribes vernacular architecture exclusively to the past.

In the previous chapter we saw that despite all socio-cultural and economic changes, Uganda is still an agrarian society. Given that the profession of architecture can be clearly attributed to the service sector, it is not surprising that in 2018 there were only 178 registered architects in Uganda.[11] When asked in a conference if this meant that there was all the more work for the few architects in Uganda, Adengo responds "no - people are building without architects; many don't even know what an architect does."[12] While the increasing use of industrialised building materials has led to a partial professionalisation of the construction sector, most of the built environment today is still architecture without architects, or non-engineered structures, as one would call them without connotation.

Three Kinds of Vernacular

When Rudofsky stated that our image of vernacular architecture is distorted by a lack of documents, images and other material[13], it is equally true of contemporary, anonymous buildings. Paradoxically, it seems that it is the preoccupation with vernacular architecture seen as a historic condition itself that has contributed most to this circumstance.

Sixty years after the exhibition Architecture without Architects, the example of countries like Uganda, whose building culture continues to be characterised by anonymous architecture, raises the question of how accurate or useful our conception of the term vernacular still is.

As the brief description of the architectural history of the Central Region of Uganda has shown, both historic and contemporary buildings are mostly products of the same kind of making. Although the development of the later is much shorter, and the building materials used are generally marked by complex, energy-intensive production, they nonetheless emerge from a collective process of trial and error and are as vernacular as their historic predecessors.

In the same way that Rudofsky had to introduce the concept of vernacular to describe something for which there was no previous label, it is the expansion of the common concept of the label that allows for the necessary distinction between different kinds of vernacular. In the context of this work, we will therefore refer to traditional buildings, such as the Kiganda, as historic vernacular, to buildings of the intermediate state like the typology described by Kikule and Jupe as transitional vernacular, and to the new anonymous buildings as contemporary vernacular. All three vernacular typologies will subsequently form the basic architectural vocabulary of the case study buildings, or as Rudofsky put it "above all, it is the humaneness of this architecture that ought to bring forth some response in us."[14]

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Lost Practice
The Historic Vernacular

Maximilian Weidacher

The oldest comprehensive description of a Kiganda, the traditional home of the Baganda, dates from 1911 and is again by John Roscoe. At first sight, the records give a detailed picture of the typology. However, if one compares Roscoe's descriptions with those of Trowell and Wachsmann, published some 40 years later, a discrepancy in the structural composition of the buildings documented emerges. While Roscoe presents to the reader an elevated, single-shell basket structure, Trowell and Wachsmann describe a much more complicated, double-shell construction that consists of a tectonic roof structure and a suspended basket that forms the interior of the structure. In order to gain a proper understanding of the Kiganda, we will first try to resolve the discrepanciesthat arise from the different descriptions.

Three Hypothesis

Assuming that the single-shell basket structure described by Roscoe was indeed the only construction method known to the Baganda in 1911, the much more complex double-shell construction method would have had to evolve in less than 40 years. Given the typically long development times of vernacular construction methods, the structural change from a textile-based shell to a tectonic system in such a short period of time seems very unlikely. Jupe and Kikule's suggestion that the traditional Kiganda has been gradually replaced by a square gabled typology since the 1940s makes this hypothesis even less plausible.[1] The second hypothesis would also assume that Roscoe's description of the construction is complete, but that the statement that the Baganda knew only one method of construction is not true. Since Roscoe's description of the Kiganda refers to the construction of a representative building within the royal enclosure, it seems almost impossible to us that the Baganda knew a much more elaborate and complex method of construction, but did not use it in the construction of a representative building. The third hypothesis must therefore be based on the assumption that there are gaps in Roscoe's documentation and that his description, as the only source, gives a false picture of the traditional Kiganda. Since Roscoe's records do not contradict Trowell's and Wachsmann's descriptions, but rather a coherent structure can be constructed by superimposing the two, the last hypothesis seems to us to be the most likely on the basis of the available documents.

Trowell and Wachsmann classified the Kiganda as belonging to a group of vernacular typologies that they termed "beehive dwellings". According to the authors, there is a great variance of this type within the interlacustrine region, among which the Kiganda represents the highest stage of development. Trowell and Wachsmann explain the simultaneous deviation of the Baganda buildings from the general

fig.1 Photograph "Native House With Pinnacle"; Documented by John Roscoe.

fig.2 “Typical Uganda Hut”; Photograph of a Kiganda Hut documented by John Roscoe (1911).
fig.3 (right page) Residents of Namasuju (near Bowa Hill) demonstrate the demarcation of a circular building.

tectonic principles of the type as follows: “Externally, with the thatched roof reaching down to the ground, it gives the impression of a large beehive. However, the roof poles extending from the apex are not anchored to the ground by their bases, but are lashed to the tops of a circle of upright poles driven into the ground. (...) Tectonically, both the Ganda and Kiga houses represent a transitional state between the beehive type and the widespread African house type consisting of a conical roof supported by a cylindrical wall.“[2]

Lost Practice

A much more detailed and comprehensive description of the building process of traditional Baganda construction than that of Roscoe or Trowell and Wachsamann is offered by the French building researcher Sébastien Moriset’s *Introduction guide to the preservation of traditional thatching of the Buganda community in Uganda* from 2021. As the Kiganda had completely disappeared from Uganda’s building culture as a living vernacular typology by the time of publication, Moriset’s descriptions document the construction of a reconstruction building. They also show various restoration works on existing buildings as part of the restoration of the Kasubi tomb complex, the burial site of the Buganda kings, which has been under the protection of the UNESCO World Heritage Programme since 2001. Although Moriset does not provide the reader with clear pictorial references, it is apparent from the photographs that the historic buildings on the site correspond to Roscoe’s and Trowell and Wachsmann’s descriptions. However, as we will see in more detail later, the reconstructed building described introduces a hitherto unknown element: a ring-shaped masonry structure that supports the conical roof. The lack of pictorial or historical references is even more irritating in the case of the masonry, since Trowell and Wachsmann point out that it is precisely the absence of a cylindrical wall that is a special feature of the Kiganda. Moriset himself does not comment on the historical development of the Kiganda in his book; according to the author, his work is essentially based on “(...)

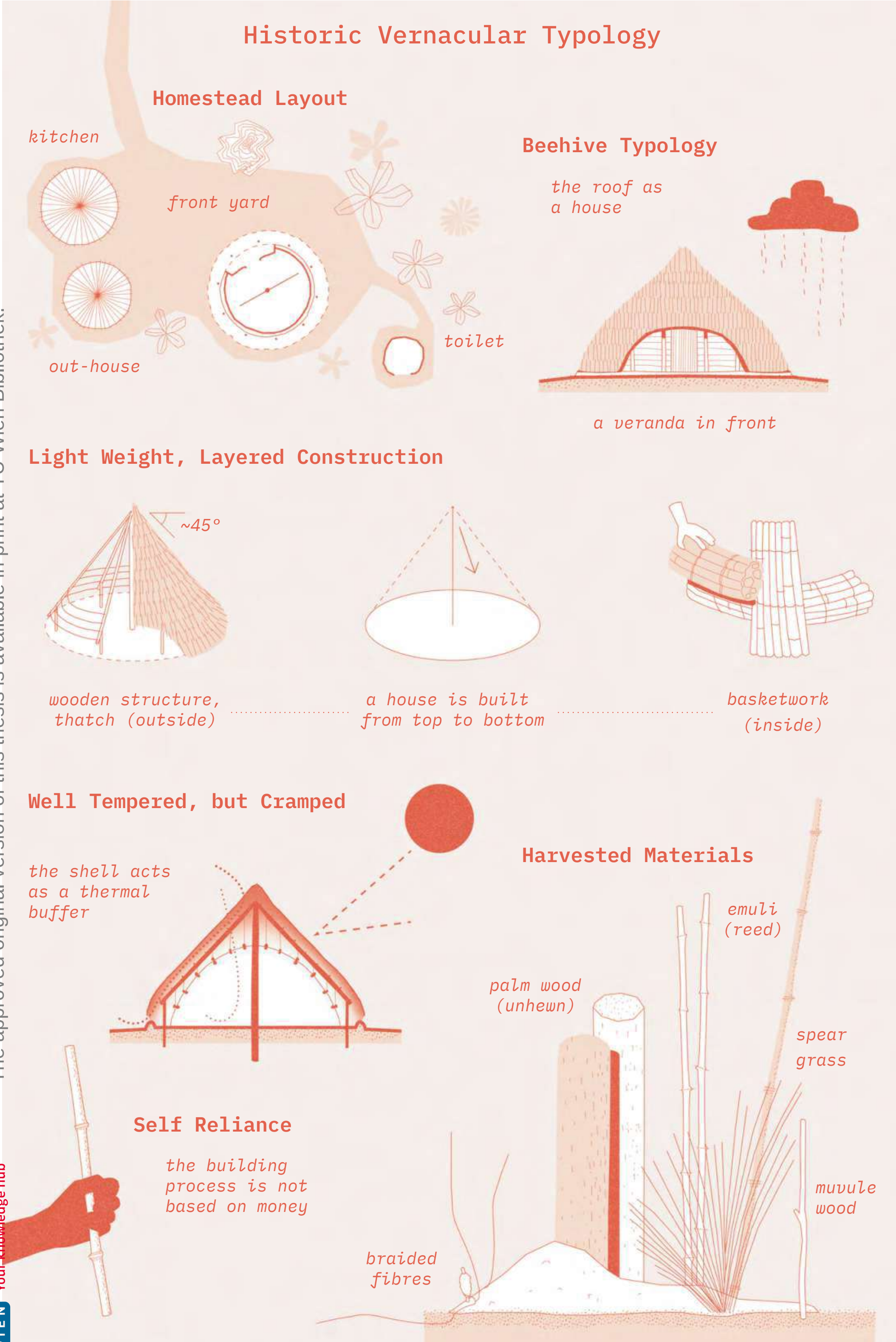

fig.4 Key characteristics of the Kiganda, the historic vernacular typology of the Baganda people. If you turn to the next chapter, you can compare the historic with the contemporary vernacular typology.

recording the knowledge of the last craftsmen in order to prevent it from being lost" and the manual is primarily "(...) designed to convey technical information only".[3] It therefore seems likely to us that the reconstruction building retroactively ascribes or adds translated construction principles of the contemporary vernacular typology to the historic vernacular building method. As irritating as the supposed reconstruction may be from the point of view of building history research, the gesture of combining historical and contemporary building techniques in an uninhibited way appears as promising as forward-looking to us.

With regard to the divergent descriptions of the Kiganda, we felt it necessary to point out the open questions and contradictions that arise from the comparisons. Building on the previous considerations, we will proceed with a general introduction to the Kiganda and then move on to a detailed description of the building process, the construction and the materials used, taking into account the sources mentioned so far.

On our way to the construction site, as we leave the main roads, we pass many plots of land that seem abandoned and where nature has taken over. These plots of land have one thing in common: a small, poorly constructed house, or rather a shed, too small to live in, yet made of bricks. Doors and windows are locked. One day I ask Patrick if he knows the purpose of these small buildings. Without hesitation he tells me that these houses are a symbol of ownership. Once there is a house on a piece of land, no person or family can claim someone else's property as their own. As we move on, I remember Roscoe writing that it was the first duty of a peasant and his family to build a house when settling on a new piece of land.

The Historic Vernacular Typology

From the outside, the Kiganda appeared as a steep, grass-covered cone, topped by a pointed pinnacle. From an uplift in the conical roof, a shallow porch articulated a front. In the center of this porch was the only opening in the building - the entrance or exit. Historical illustrations show a diameter of ten meters at the widest point, a building height of about five meters and a resulting average roof pitch of between 45° and 50°.

From a structural point of view, the Kiganda was a symmetrical lightweight building which was composed of a tectonic structure and a suspended basket shell ceiling. The uprights of the structure were made from unhewn, round trunks of palm trees, safe from termite attack; the rafters were made from the lighter, yet dense and rot-resistant wood of the Emikomba tree. The second shell, the suspended basket ceiling, was made entirely of stalks of a reed called emuli. The basketwork was probably tied together with sisal cords and fastened to the supporting structure with strips of tough tree bark. The shell of a traditional Kiganda reached down to the ground, so that the entire interior had a straw-coloured surface.[4] According to Trowell and Wachsmann, the floor of a house was covered with fresh grass every day.[5]

The thick grass thatch also reached almost to the ground, where it merged into a 30 cm high perimeter wall of compacted earth. The ring-shaped threshold prevented surface or rain water from entering the building. The absence of window openings and the insulating effect of the grass cover protected the interior from overheating during the day. The space between the closed roof skin and the basket shell additionally acted as a thermal buffer, allowing heated air to rise and diffuse through the grass roof.

Reconstructing a Kiganda

The pictures on the following pages show the reconstruction of a Kiganda as documented by Sebastian Moriset. Bear in mind that this documentation is limited from a historical point of view, as in addition to foreign components, especially the ring masonry, a variety of industrialised materials, such as metal wire, nails and milled timber have been introduced into the construction process. As the selection of images can only show fragments of the building process, we recommend reading the original paper. You find the link at the end of the chapter.

(1) To Build is to Harvest

Construction began with the collection and preparation of building materials. While the actual construction was carried out by men, it was the women who sourced much of the building materials.

fig.5 Cutting mature spear grass.

One of the main materials was thatch, made from spear grass. Mature grass was cut close to the ground, tied into bundles and left to dry. Once dry, it was sorted and tied into smaller bundles of 5-6cm diameter for the main part of the roof and larger bundles of 10-15cm diameter for the base. According to Morriset, almost 50% of the grass harvested was discarded during processing.

As for thatch, large quantities of reed (emuli) were needed for the construction of the basket shell ceiling. After being cut, the reeds were tied into bundles, transported to the site and left to dry. Once dry, the reeds were smoothed with a knife blade to remove the remaining leaves and to smooth out the knots. The finest and straightest reeds were further polished with a damp cloth covered in sand. These reeds were used for the visible interior of the basket.

fig.6 Smoothing reed (Emuli) knots.

As the whole structure was based on weaving and binding, a variety of finer yet tough fibers were required. Ropes were made of either braided sisal or strips of tree bark fibers (Ebinsambwe). Palm frond sticks (Amavuvuume) and water grass rope (Enjulu) were used for decorative elements.

fig.7 Braiding sisal rople.

(2) Tectonic Roof Structure

The first element to be erected was the central post. Second came the outer posts, which were arranged in a circle and spaced at regular intervals. Larger huts required more rows of posts in between. All the posts were made of unhewn palm wood - a wood resistant to rotting and termites. According to John Roscoe, the posts were set in 2-foot deep holes in the ground and held in place by compacted earth.

fig.8 Making the first ring around the center post.

Regarding measurements, it is important to note that all dimensions were measured either in fixed units, such as the knots between reed segments, or in anthropometric units. Common units were: steps (foot), cubits or fingers (pouce).

After the poles had been positioned, rafters were installed. The upper end of the rafters rested on the central post, the lower ends on the outer posts. The average pitch of the rafters was between 45° and 50°. The rafters were made from Emikomba wood.

fig.9 Rafters of a reconstructed building.

Next came the battens, which were made from branches of the Musambia tree. As nails were not available at the time, they were probably tied to the rafters with rope made from natural fibers. The distance between the battens was about 40-50 cm, or one cubit. The battens served three purposes: on the outside they were used to tie bundles of thatch and on the inside they were used to hang the basket-shaped ceiling. In addition, the structure served as a convenient scaffold for the next steps in the construction process: making the ceiling.

fig.10 Worker sitting on the battens.

(3) Weaving and Tying

Making the ceiling started with sorting the reeds. The long and straight ones were set aside for the ceiling itself, the crooked and shorter ones were used to make structural rings of the basketwork. The rings of the basket came in pairs; according to Morriset, the rings visible from inside, measured 12-14 cm in diameter (requiring 50 to 60 reeds) and the opposing ones on the outside, measured 7-8 cm in diameter (requiring 20 to 30 reeds). To make the rings, long bundles of reed were tied, bent with mallets and cut to the right length. The pairs were tied together with sisal rope.

fig.11 Tying bundles of reed with sisal rope.

fig.12 Working on the suspended ceiling.

Between the ring-pairs was the reed ceiling itself. Historical examples at the UNESCO site of Kasubi Tombs in Kampala show a range of thicknesses from 10 cm to 38 cm. The overall thickness of a ceiling depends on two parameters: the span of the roof and the level of finish.

Morriset describes the process of making the ceiling as follows: "The rings are installed from the top moving downwards, as the ceiling is being built. For each new ring inserted, reeds are inserted to form the ceiling. The two operations are inseparable. The reeds are forced in from below. Once pushed in, their position is adjusted using the work stick (Embwa). Once all the reeds are placed, the connection between the large lower rings and the smaller upper rings is reinforced with quadrupled binding wires. In order to be able to pass the binding wires through the very dense ceiling, the reeds are spread using the stick (Embwa)." The pictures show that there are two teams working on the suspended ceiling at the same time: one the outside of the shell and one on the inside.

fig.13 The completed ceiling.

(4) Thatching the Roof

Compared to other thatching techniques, the Kiganda is unique in that the thatch was laid 'upside down', with the stems on the inside and the leaves exposed at the bottom. Furthermore, only the bundles at the base and those hidden beneath the surface were tied down, leaving most of the rest to be held in place by compression from the top layer. This allowed for partial replacement, making maintenance easier. The thatch of a Kiganda was about a foot thick. At the lower end of the roof, the eaves were trimmed so that no grass touched the ground. At the top, a pinnacle made of bundles wrapped around a pointed stick kept rainwater out of the building.

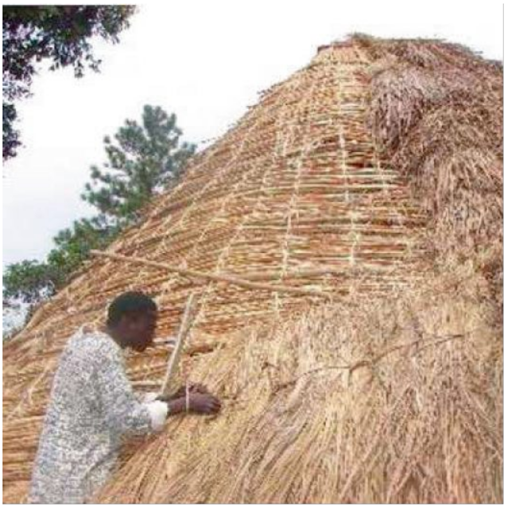

fig.14 Tying bundles of thatch.

(5) Details and Finishes

The entrance to a kiganda was made with particular care. The finest and straightest reeds were reserved for the underside of the ceiling and the vertical walls that formed the veranda. Morriset comments that the appearance of the entrance would show the craftsmen's skills and the quality of their work.

The door, a stitched mat of reed (emuli), could be slid to one side of the opening in a log with a groove set into the floor. Three wooden posts held the door in place.

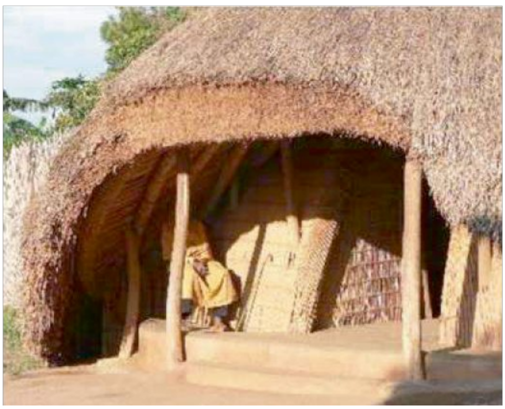

fig.15 The entrance to a reconstructed Kiganda.

For the floor, the ground was first dug up and leveled. Next, a layer of good soil was spread evenly, trodden, stamped and finally tamped down with short sticks. To seal the surface, the floor was rubbed and beaten with young plantain shoots. Finally, the floor was carefully covered with a carpet of fine-leaved grass.

(6) House Life

Inside the Kiganda, a central textile wall, made of bark cloth, divided the conical room into two equal halves. The front half of the room was the public sitting room, and the back half was the private sleeping room. The curtain wall did not extend to the edge of the house, so that it was possible to move along the sides from one half of the room to the other. In larger Kigandas, additional curtains formed pockets (recesses) along the inside of the shell. These pockets served either as individual sleeping quarters or as storage space for miscellaneous household items or agricultural tools.[6]

fig.16 Replica of a bark cloth curtain.

The only pieces of furniture found in historical descriptions are simple wooden bedsteads set into the floor and chairs, the use of which was reserved for men.[7] The predecessor (and simpler version) of the wooden bed was a mound in the floor, also made of compacted earth.

Fire and Outbuildings

According to John Roscoe, there was a square fireplace in both the front and rear room. The fire provided warmth and light for the inhabitants, and the smoke protected the building from insect infestation. However, the sparks and flames posed a serious threat to Baganda dwellings, which were built entirely of highly flammable materials. The frequency of such fires can be inferred from a behavior that Roscoe notes: "The people did not seem to be much disturbed when a house was burning; they seldom attempted to extinguish the fire, but got out their goods as quickly as possible and left the building to burn down".[8]

According to historical accounts, the Baganda built smaller outbuildings alongside the main house, such as an outhouse kitchen (probably to reduce the risk of fire in the main house), a reed screen used as a private bathroom for the husband and wife[9] or a workshop hut for making bark-cloth. Roscoe states that, although it was rare among farmers, "if a man married more than one wife he built a separate house for each; the houses were generally side by side and enclosed by a fence."[10]

No information can be found on the construction and composition of the outbuildings, but it seems likely that the construction methods were not very different from those of the Kiganda. Given the limited availability of long-distance transport at the time, we can assume that all building materials, again like those of the Kiganda, were locally available, renewable resources.

fig.17 Making bark-cloth in an out-house; documented by John Roscoe.

1 Oliver, P., et al. (1997) *Enceclopedia of Vernacular Architecture of the World*, pp. 1998. Cambridge: Cambridge University Press.
2 Trowell, M. and Wachsmann, K. P. (1953) *Tribal Crafts of Uganda*, p. 18. London: Oxford University Press.
3 Moriset, S. (2020) I*ntroduction guide to the preservation of traditional thatching of the Buganda community in Uganda*, p. 5. Nairobi: UNESCO [online]. https://hal.science/hal-03220208/document (Accessed: 11 December 2021).
4 Roscoe, J. (1911) *The Baganda: An Account of Their Native Customs and Beliefs*, p. 372. Cambridge: Cambridge University Press.
5 Ibid.
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7 Roscoe (1911) *The Baganda: An Account of Their Native Customs and Beliefs*, p. 408.
8 Ibid., p. 21.
9 Ibid., p. 19.
10 Ibid., p. 83.

Common Practice
The Contemporary Vernacular

Maximilian Weidacher

Looking at an average house in the Central Region, it is hard to imagine that contemporary construction is a product of lost practices. On one side, we find a dome-shaped, lightweight building made from locally available, renewable materials; on the other side, there is a single-story bungalow of solid construction with a pitched roof. In the previous chapters, the non-material characteristics that the historic and contemporary vernacular typology share have been already described, however, a closer examination of a transient vernacular typology as documented by Kikule and Jupe reveals further much more immediate similarities. This typology appears to be of particular importance, as it bridges the gap of the supposed rupture between lost historic and contemporary building practices.

The Transient Vernacular Typology

Unlike the conical Kiganda, the transient vernacular typology is built on a square layout with a side length of about seven meters. The building form follows a horizontal disposition consisting of a perimeter rim, vertical walls and a pitched roof. Although the outer appearance of the two types of building is inherently different, both the perimeter rim of compacted earth, which protects the house from the ingress of surface water, and the closed facade are the first characteristics that both typologies share. From a structural point of view, the transient typology, like its predecessor, is a symmetrical lightweight structure composed of a primary load-bearing structure and a secondary envelope. The load-bearing structure continues to be made up of palm-wood posts, which are still anchored directly into the ground. The walls between the posts consist of a wattle of elephant grass, which are lined with clay.[1]

The axonometric drawing on the right side shows a low-pitched hipped roof, with rafters spanning from the outer walls to a central wall that acts as a ridge. The top of the wall ends approximately at the lintel, giving the eaves a height of about 180-200cm. According to the authors, the roof is still thatched but the thatch is made from dried strands of the central part of the banana tree instead of spear grass. Another important element that can be found in both the historic as well as the transient typology is the veranda in front of the house. In the case of the Kiganda, the veranda was created by raising the roof envelope which reaches down to the ground; in the case of the transient vernacular typology, it is created by a roof overhang of about 60cm. An additional quality of the roof overhang is that it shades the facade and protects the walls from rainwater.

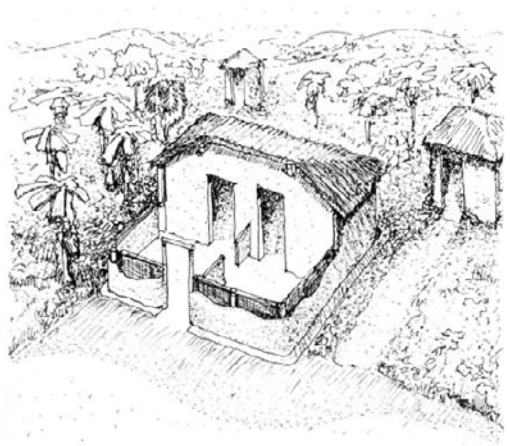


fig.1 Axonometric drawing of the transient vernacular typology; documented by Kikule and Jupe.

Instead of the single division that split the historic circular building into a public front and a private rear, the square (or rectangular) building is usually partitioned into four rooms: a living room, a parents' room and two storerooms/bedrooms. Kikule and Jupe state that the interior is divided either by packed earth walls or by bark cloth hangings.[2]

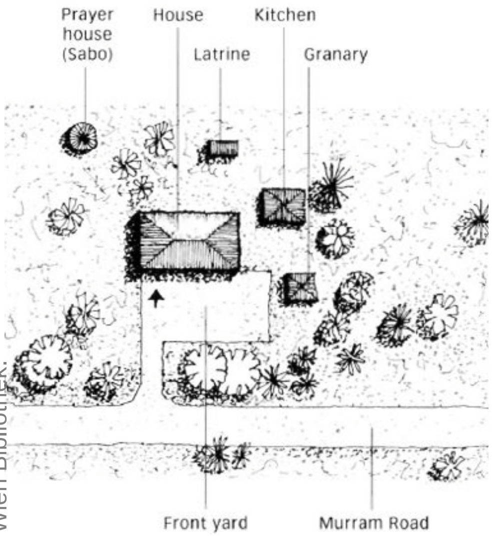


fig.2 Allocation plan of a typical Baganda homestead; documented by Kikule and Jupe.
fig.3 (right page) A typical house and homestead in Nakaseke district.

Moving to the outside, the layout of the transient vernacular homestead is very similar to that of the historic vernacular homestead. In both cases, the main house is preceded by a shaded and often un-grassed front yard, with outbuildings such as the kitchen house, granaries, a prayer house, and a bathroom in close proximity. The homestead itself is usually situated on a slope, close to a village (murram) dirt road and surrounded by a field of plantain, mutuba and lusambya trees, all of which provide either food or building materials.[3] However, the popularity of the transient typology was only short-lived, as it was soon replaced by its modern equivalent, a bungalow-type building using industrialised building materials.[4]

Customs and Common Ideas

Today, this bungalow is the most common residential typology and even in the rural areas of the Central Region only the very poor live in houses which are made from locally sourced, non-industrialised materials. In contrast to the historical vernacular typology, whose variance was only apparent in size and accuracy of workmanship, almost no two buildings appear to be the same. Although new methods of construction and the availability of industrialised building materials and elements allow for a greater degree of formal variety and individual expression, the collective adherence to a single type of building however appears as a continuation of a customary concept. Like the Kiganda, any given bungalow can be seen as the closest possible approximation to the ideal home, according to the financial means of the owner, with the status value determined primarily by the novelty value of the materials used and the money spent.

On our trip we repeatedly noticed a prevailing sense of commonness in Ugandan culture. Whether it is cuisine, agricultural crops and practices or construction, there appears to be a strong collective bond and agreement to common ways of doing things. In this respect, why would you want to do things differently?

The Contemporary Vernacular Typology

In the last section of the research chapter, we will look at what we have labelled as contemporary vernacular and its implementation, the common practice.

Like its predecessor, the contemporary vernacular typology is also characterised by a horizontal disposition. At the first layer, the perimeter wall of compacted earth has been replaced by a plinth that raises the building off the ground; at the second layer brickwork replaces the wattle and daub walls that support the third layer, which is either a pitched or a hipped roof. From a structural point of view, the typology of the contemporary vernacular is that of solid construction, although with a common wall thickness of one brick width, i.e., 10-12cm, it does not really live up to the name. The brickwork of the external and internal walls is often held together by a surrounding ring of reinforced concrete, which also forms all the lintels of the openings. In the final rows of bricks there are vents which ensure constant ventilation of the interior.

Compared to the transient typology, the pitched roof is unchanged in shape and has an average pitch angle of around 30 degrees.

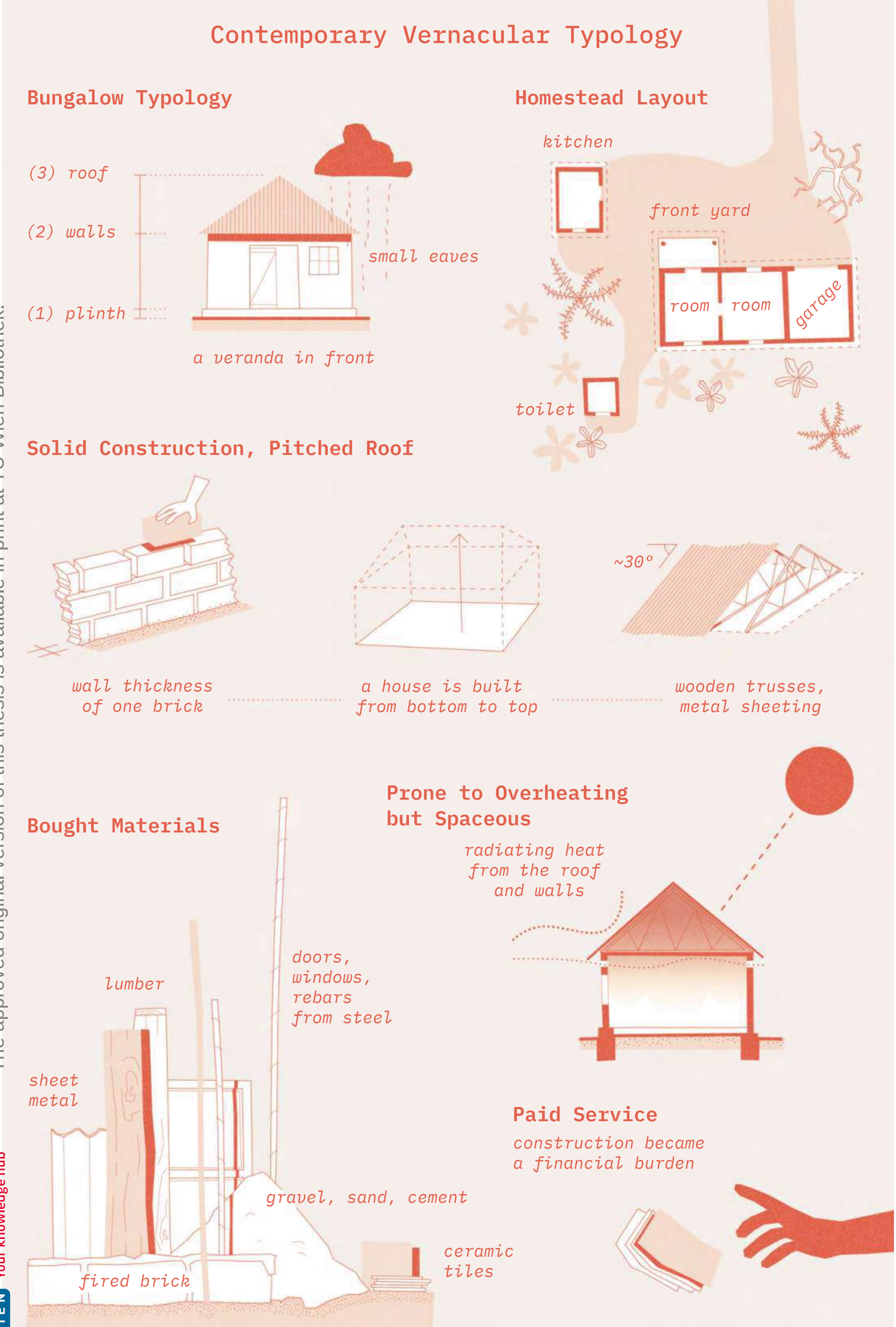


fig.4 Key characteristics of the contemporary vernacular typology. For a comparison with the historic vernacular typology, the Kiganda, you can turn back to the previous chapter.

Structurally, both rafter roofs and trussed roofs are found, with roof loads usually being transferred through the external walls. Thatched roofs have been replaced by corrugated steel sheets of various colors and shapes. The houses have short roof overhangs, probably due to the high cost of materials and the greater durability of the brickwork compared to mud walls. However, the increased room height and short roof overhangs have the significant disadvantage that not only the roof but most of the building envelope is exposed to direct sunlight. The roof space itself is usually separated from the living space by a false ceiling. The strong heating of the sheet metal roofing during the day, combined with the lack of ventilation of the roof space, generally results in overheating of the interior rooms, especially in the second half of the day.

Ideally, the exterior and interior walls are plastered with cement render and painted; the plinth is clad with large-format slabs of quarry stone; the floor is made from cement screed, either tiled or coated with a cement slurry; the false ceiling separating the interior from the roof space is made of a wooden lattice with wire reinforcement, plastered with cement. Windows and doors are preferably made of steel profiles, the fields filled with steel sheet or glass panes. Particularly in rural areas, financial resources of the owners are often exhausted by the construction of the shell, so that there is no further finishing of the house once the windows and doors have been installed.

In the contemporary vernacular typology, the front of a house is still marked by a veranda, but due to the short roof over-hang, it is mostly added in front of the building. As in the Kiganda typology, the roof of the veranda is supported by pillars. In many cases, the front is the only façade of a house that is plastered and painted, further articulating the symbolic significance of the front of a house.

The common layout of the exterior of a homestead, as well as the outbuildings, remain unchanged, as compared to the preceding vernacular typologies. Unlike the main building, which, apart from the structure of the roof truss, consists exclusively of industrialised building materials, outbuildings such as the kitchen are often built in the style of the transient typology. The exclusion of the kitchen results from the circumstance that even today a large part of Uganda's population cooks with wood or coal; the exclusion of the latrine is a result of the lack of corresponding sewage infrastructure.[5]

fig.5 Videos proposed by YouTube when searching for "Building a House in Uganda".

Common Practice

In order to develop a deeper understanding of contemporary common practices in the Central Region a method was employed that may seem unusual at first sight. After an extensive search for useful information, we finally found what we were looking for on YouTube. At second glance, the source could not be more coherent – popular media as a means to observe the production of common culture.

The images on the following pages are retrieved from a video published on YouTube in 2019, which documents the construction of a residential house in a town called Kakiri, approximately 30km northwest of Kampala.[6]

Again, as with the historic vernacular typology, the selected pictures show only fragments of the building process. For a more complete understanding, it is recommended to watch the whole video. The link is provided at the end of the chapter.

(1) Layout and Excavation

As with most construction today, the building process begins with layout, followed by excavation. The outlines of the buildings and the axis lines of the foundations are laid out using posts and strings.

fig.6 Layout and manual excavation.

Building materials are delivered alongside the manual groundwork. Small lorries arrive several times with fired bricks, sand and bags of cement.

fig.7 A truck delivers bricks.

fig.8 Mixing cement mortar on the ground.

(2) Bricklaying

The foundations are made of bricks and cement mortar. There seems to be a strict division between the workers who mix the mortar and move building materials and those who do the bricklaying. Once the foundations are complete (after 7 layers of bricks), the plinth is filled with soil from the excavation.

fig.9 Laying bricks for the walls.

While the bricks of the footings are laid in headers, the bricks of the exterior as well as the interior walls are laid in stretchers, resulting in a wall thickness of around 12cm. First the corner walls of the building are constructed and then joined together in a second step. Strips of plastic sheet act as a moisture barrier between the footings and the walls. Thick layers of cement mortar compensate for the irregular shapes of the manufactured bricks. After

fig.10 Bricklayers on a makeshift scaffold.

several rows have been laid, the vertical joints between the individual bricks are carefully filled in a second step. This adds to the already high amount of mortar used.

As soon as the walls are too high to work on, a makeshift scaffold is erected. The vertical uprights are anchored directly into the ground; gaps in the brickwork serve as temporary supports for the horizontal beams of the scaffold.

fig.11 Tying rebars.

In terms of the positioning of the windows and doors, it appears that most of the openings have a corresponding counterpart. Although such an arrangement is a good precondition for cross ventilation of the building, there are no ventilation elements as part of the masonry.

(3) Concrete Works

As the final layers of bricks are laid, preparations for the upcoming concrete work begin. The first step is to construct a ring beam, which will hold all the walls of the building together and also act as a lintel for the door and window openings. Fig.11 shows that the reinforcement of the ring beam consists of only three rebars and triangular cages.

Another reinforced concrete component are the columns that support the porch roof. Structurally, the veranda is the most complex part of the house. The effort put into it is another indication of the prevailing importance of the main entrance and the area around it.

Once the concrete work is complete, an additional 5 rows of bricks are placed on top of the ring beam to increase the height of the rooms by another 60-70cm.

(3) Building the Roof

A truckload of dimensional lumber arrives at the site. New people appear with it - apparently a different craft. The construction of the roof begins with the setting of the foot purlins. Precut timbers are attached to the concrete ring beams with steel straps.

fig.12 Setting roof trusses and rafters.

Timber trusses are assembled in situ and nailed to the foot purlins. Ridge and gable timbers are spliced and fitted to complete the roof geometry; additional diagonal bracing is added at the very end. The pitch of the roof appears to be between 30° and 35°.

Next, close-set battens are attached to the roof structure. All protrusions are shortened in a separate operation and the rafter heads are covered with a fascia board. According to the pictures, the eaves measure about 40-50 cm.

fig.13 Nailing the battens.

fig.14 Tampering the cement floor.

Roofing is done by the same people who did the framing. Corrugated sheets are cut by hand and nailed to the battens. To fasten the sheets, the workers use special nails with large dome-shaped heads and rubber washers.

fig.15 Laying and nailing roofing sheets.

To complete the work on the roof, a wooden lattice with a fine metal mesh nailed to it is installed on the underside of the trusses. The mesh is covered with cement plaster, separating the interior space from the attic. The entire roof space appears to be left unused.

Like the ceiling, all the floors are made of cement screed. Large quantities of cement are used in the making of these two components.

(4) Doors and Windows

All windows and doors are made of steel. The square tubing and flat profiles of the elements are cut and welded on site. Although the work is carried out on the ground, the finished frames appear flat and square. Once the frames and sashes are complete, decorative grilles are assembled and fitted to the inside of the windows. As a consequence, the windows either slide or, in most cases, open outwards. To open or close a window you have to reach through the grilles.

fig.16 Welding windows and grills.

A common feature of older houses are ventilation blocks above each opening. However, practice is changing and, as in this case, the louvres are now often part of the window elements; the louvre blades are made of flat steel. When all the elements are finished, they are lacquered.

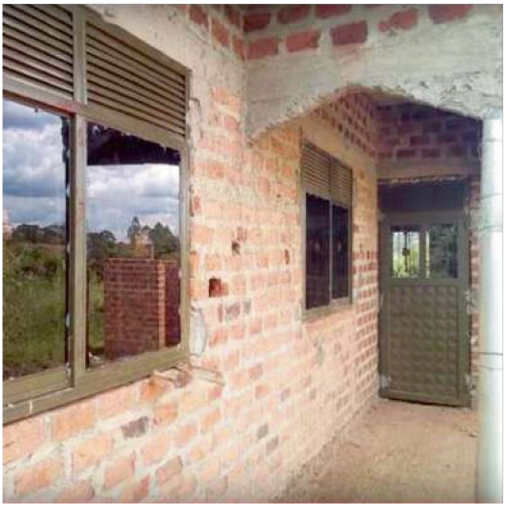


fig.17 Installed doors and windows.

For installation, the windows and doors are secured to the masonry with mortar through bars previously welded to the studs. Finally, large-format glass panes (in this case dark tinted glass) are inserted and the fittings are mounted. With the windows and doors in place, the authors comment that "the house is now ready to live in".

(5) Toilet Outhouse

In the last part of the video, the workers are building a toilet block next to the main house. The construction begins with the digging of a deep cesspit. The cesspit is not sealed against the ground on any side, which makes contamination of the groundwater very likely. The materials used in the construction of the sanitary rooms are the same as those used in the construction of the house.

fig.18 Finished sanitary outhouse.

Tools and Time

From a European perspective, it seems almost unbelievable that the majority of buildings in Uganda are still constructed entirely by hand and, furthermore, mostly without the use of power tools. External energy sources are only used on site to deliver building materials and, towards the end of construction, to make the steel windows and doors. Although the buildings are constructed without the use of machinery, the number of hand tools used is not much greater than what he have seen at the example of the reconstruction of a Kiganda as documented by Moriset: shovels, string and a plumb line, a measuring tape, buckets and wheelbarrows, trowels, hammers, a hacksaw and a bow saw for wood. The building process captured in the video takes only about a month. According to the authors, the house could have even been built much faster if there hadn't been delays in the delivery of building materials.

In Comparison

A key difference between the contemporary vernacular typology and its predecessors is a particular aspect of the building process. Although all three typologies are the product of a collective effort based on trial and error, it was the use of industrialised building materials that turned the construction of a house into a major financial burden for the average homeowner. The use of the new types of building materials results in costs on three levels: instead of collecting renewable building materials from the immediate environment, building materials are purchased from various building material dealers; the transport of purchased building materials results in further transport costs; the use of industrialised building materials goes hand in hand with a partial professionalisation, where the building process shifts from a self-reliant skill into a paid service. Today, building a house requires at least one mason for the walls, a roofer for the roof and a metal worker or carpenter for the doors and windows.

While a comparison of the three stages of vernacular architecture of the Baganda reveals a multitude of constant or transformed elements and characteristics, an approximation to Western architecture, or the adapted idea of it, cannot be dismissed. Despite all the obvious disadvantages of the contemporary vernacular typology compared to its historic counterparts, the underlying collective development process must be understood as a direct expression of a common desire for cultural transformation.

Assuming that architects or engineers can, in principle, participate in the development of vernacular architecture, the multitude of contradictions and problems inherent in the contemporary vernacular typology and common practices create a highly ambivalent starting point. On one hand, there are problematic aspects, such as the threatening loss of cultural identity, and increased environmental impact due to the use of energy-intensive building materials, and the associated enormous financial burden on a population that is already struggling with poverty. On the other hand, there are a number of potential improvements to the housing situation, such as more spacious, better-lit and ventilated interiors, reduced maintenance work as well as reduced fire risk. Finally, we should not overlook perhaps the most important aspect: the high status value of the new construction method and the possibilities of formal expression that go along with it.

1 Oliver, P., et al. (1997) *Enceclopedia of Vernacular Architecture of the World*, pp. 1998. Cambridge: Cambridge University Press.
2 Ibid.
3 Ibid.
4 Ibid.
5 Explanations of common practices and the contemporary vernacular are based on the authors' own observations.
6 Yandt, J. and Brian, M. (2019) *Building a house in Uganda* [online]. https://www.youtube.com/watch?v=KEKyv0qRO48&list=PLyy3iVpHlHEK-gMKAMLRWhgpubO1yJDP5Q&index=11 (Accessed: 03.05.2023).

B

Planning

Pre-Design
Building Typology and Thermal Comfort

Benedikt Mass

In the previous chapters we have gradually moved into the subject of architecture and building in Uganda. Looking at different points in time, we have traced the metamorphosis of vernacular architecture and looked at the related lost and common practices.[1] On the basis of these observations, we intend to continue to explore transformation, yet from another perspective. To start with, we want to analyse the relationship between typology and thermal comfort. While findings will inform decisions of the subsequential design phase, we aspire to draw meaningful conclusions that are applicable not only at the scale of the immediate project region, but within a larger scope yet to be defined.

Scope(s) and Project Region

There is a long-standing scientific tradition of mapping and categorizing the observed, to simplify the seemingly inconceivable, in order to help recognize patterns and interrelations between different phenomena. Architectural research, especially on vernacular building traditions, is no exception to that rule, even though it can be hard to define a framework for categorizing the plethora of different building traditions and typologies, due to the large number of possible classification criteria.

The form and shape of vernacular buildings is influenced by many parameters shared by many regions on different scales around the globe. Single factors have rarely been the basis of geographic mapping in architectural research, and many approaches to classify building typologies exist, regarding specific environmental conditions and corresponding morphological features.[2] These include climate, cultural influence, and the availability of material resources and many more.

Climate is one of the strongest and broadest determinants for the morphogenesis of a building typology, and most vernacular buildings are well-adapted to their environment by adequate passive strategies. In similar (micro)climatic conditions around the world, a convergent evolution of architectural traditions can be observed beneath the surface of local morphological peculiarities shaped by material availability or cultural preferences. In tropical architectures, thatched roofs with a wide overhang to minimise solar heat gains, small or shaded openings that allow for constant cross-ventilation to increase subjective temperature perception and a thermal mass that corresponds with local humidity are all widely used strategies to beneficially influence indoor thermal comfort. As it also depends on geographical and geological factors, the availability of material resources is a determinant that already defines a much narrower range, allowing for many variations in constructive approaches in similar climatic zones. Finally, cultural influence, especially in vernacular architecture, is the driver behind the most diverse variations in shape, size, settlement structure etc. that can coexist within a very narrow geographic area.

In much the same way as it can be challenging to categorize existing building traditions, when we try to define the scope of this thesis, manifested as a project region for which our findings are applicable, we soon reach a point where different factors define different geographical boundaries of different scale. In order to better categorise the observations, considerations and results of our work, we have defined three project scopes (see next page, fig. 1).

Starting with the broadest scope, our findings on thermal comfort are roughly applicable to the tropical belt, i.e. to all tropical regions with a comparable temperature, humidity and precipitation profile (1). The next smaller scale is the country level. Our observations and thoughts on formal aspects of architecture, the use of material resources and related skillsets applies mostly to the Central Region

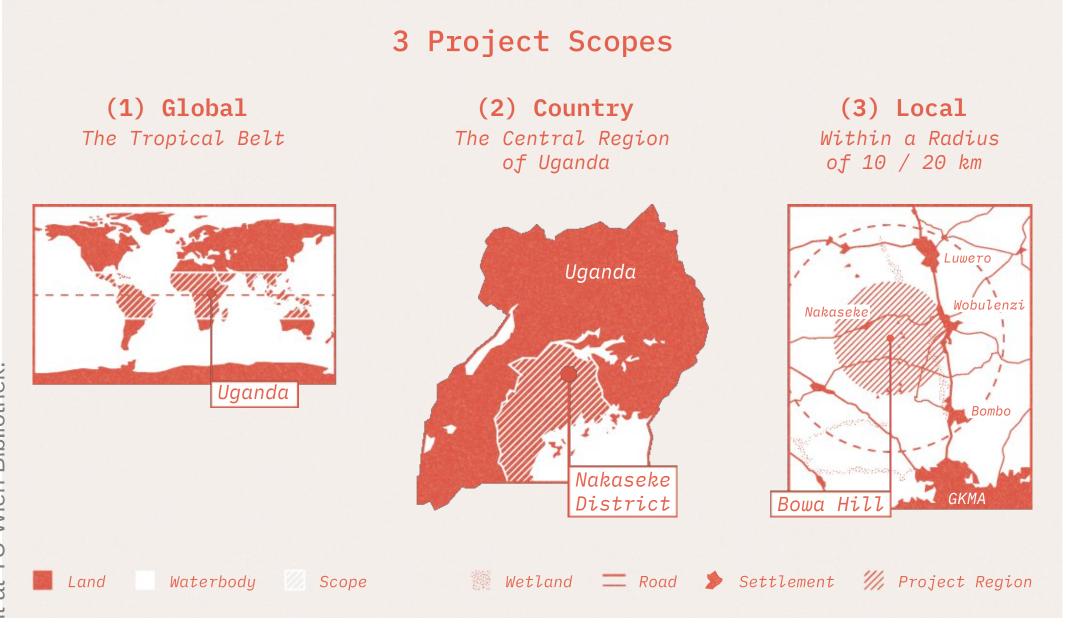


fig.1 Diagram indicating 3 project scopes including the immediate project region around Bowa Hill.

of Uganda. Another way to define a scope with a similar scale would be from a more cultural perspective and by the occurrence of the contemporary vernacular typology. The extents of such scopes (2) are characterized by the specific combination of industrial and semi-industrial materials of limited availability and a low level of processing, and relatively simple but often surprisingly inventive building techniques, all heavily reliant on manual labour.

When it comes to environmental impact calculations, production processes and the location and distance from which most of the material resources originate, define an even narrower area. In this respect, we have outlined the smallest scope, the immediate project region (3), with a radius of 10 to 20 kilometres around the project site at Bowa Hill.

While all findings can be analogously applied to other regions of comparable characteristics, more general conclusions should be drawn carefully and with awareness of local circumstances and cultural perceptions.

Parametric Design Exploration

Before moving on to the building performance simulations, we would first like to discuss our thoughts on the use of parametric tools and their potential in the context of our research.

Building performance simulation has become a recognized and widely used tool that can provide valuable information about building performance from an early design stage.[3] Facing climate change and limited fossil resources, optimizing energy demand and resilience in built environments has gained critical importance in design, to the extent that it can be a morphogenetic agent itself when integrated into the initial setup of a parametric design.[4] Simulation tools like the one used for this thesis are capable to model complex building constructions, geometries and HVAC systems, and to precisely calculate the building energy demand of these models. While all buildings we have described sofar are much less complex and do not use technical systems to optimize indoor thermal comfort, these parametric tools still provide the opportunity to accurately predict indoor thermal comfort conditions.Yet, a different focus in a potential simulation setup is required.

The aim of the pre-design phase and the parametric simulation assessments is to gain an understanding of the influence of different factors on indoor thermal comfort under the specific climatic conditions of the project region. To obtain results that are valid for the small-scale housing typologies pervalent in the Central Region of Uganda, we designed a generic proxy building, with key aspects (such as form, size, structure and materials used) derived from our research on the contemporary vernacular typology. While there seems to be only restricted potential to improve the performance of contemporary small-scale residential constructions, parametric simulations may help to determine which parameters can be changed to improve the thermal performance of contemporary vernacular buildings most effectively.

It is important to note, that in this project, parametric tools are not used for pre-rationalization[5] – i.e. as a parameter for an evolutionary form-finding algorithm – but for post-optimization[6] of an existing design within the predefined formal framework.

Simulation Workflow

The parametric definition of the proxy was set up in Grasshopper,[7] based on a building geometry modelled with Rhinoceros.[8] By using the computational framework[9] of the EnergyPlus[10] simulation engine, the Ladybug and Honeybee Plugins[11] for Grasshopper provide a powerful tool for determining and optimizing indoor thermal comfort parameters – among a multitude of even more complex calculations. To simulate the climatic conditions on site, an EPW weather file, derived from meteorological data logged at Entebbe Airport[12] was used, adapted with available meteorological data for the area of the building site from NASA's MERRA-2 project[13], which has a spatial resolution of approximately 50 kilometres.

Adaptive thermal comfort metrics and indoor operative temperature were chosen as the most meaningful performance indicators for indoor thermal comfort on which the evaluation of the simulated iterations was based. Simply speaking, operative temperature is the weighted average of air temperature and the mean radiant temperature of all surfaces in a room.[14,15] In a parametric model of a naturally ventilated building, it is a tangible indicator for the perceived temperature difference in the compared spaces, as it must be assumed that for each specific timestep, under similar exterior conditions, other external factors like humidity and air speed would stay constant in all simulated iterations. Since the static predicted means vote (PMV) model for thermal comfort does not adequately reproduce thermal comfort perception in vernacular buildings[16] and other naturally ventilated spaces, an alternative adaptive comfort model was developed in the 1990s based on empirical findings from different studies worldwide,[17] and incorporated into international norms and standards. ASHRAE Standard 55[18] provides following formulae for determining a comfort range in which 80% of occupants consider thermal conditions acceptable in a naturally ventilated space:

$$\text{upper limit (°C)} = 0.31\, t_{pma(out)} + 21.3$$
$$\text{lower limit (°C)} = 0.31\, t_{pma(out)} + 14.3,$$

with $t_{pma(out)}$ being the prevailing mean outdoor air temperature, i.e. an arithmetic average of mean daily outdoor air temperatures over a predefined period of days. Fig.2 shows the adaptive comfort range derived from these formulae. 90% acceptability limits are included for informational purposes only.

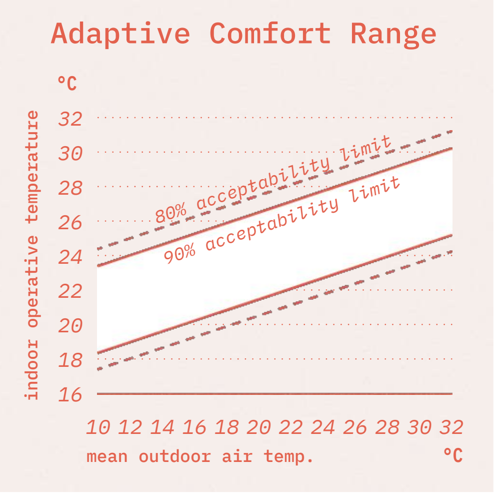


fig.2 Adaptive Comfort Range according to ASHRAE 55

For the evaluation of the thermal performance of this building, only the tendency towards overheating (the number of hours during which less than 80% of occupants will consider room temperatures within an acceptable range) is considered. While nominally temperatures also fall below lower acceptability limits, this occurs during nighttime hours only, and it is assumed that adequate behavioural measures, such as additional clothing or insulation/bedding, will take place. All results are compiled for the central bedroom (indicated in pale red in the diagram), as it is the only room with only one exterior wall surface, and therefore will yield the most meaningful results for building orientation and window size.

Simulation Parameters

The diagram on the right page (fig 3.) illustrates the definition of the proxy building by the parameters we use in the simulation setup. The parameters can be grouped into two categories, the first of which can be subsumed as "building morphology", while the second category "building constructions" comprises the thermal envelope of the building.

The first group consists of three parameters: building orientation, window size and roof overhang. Optimisation of these parameters affects the amount of direct solar irradiation and, to some extent, cross ventilation. The second group, consists of the building components roof, ceiling, wall (and floor). Adapting the building constructions and the materials used improves the thermal performance of these components.

After combining all different options defined for each single parameter, a total number of 1080 iterations is simulated using Colibri,[19] a Grasshopper Plugin designed for automating both the simulation of all possible combinations of a parametric model and, to at least some degree, the evaluation of the simulation results.

Orientation

Direct solar irradiation can have a significant effect on indoor thermal comfort. Especially when the sun is low, vertical building components are exposed to direct irradiation which heats up the interior spaces mostly through glazed windows. To simulate the magnitude of this effect on different areas of the building envelope, the building orientation is rotated counterclockwise in five 45°-steps, starting with the building aligned along the north-south axis and the bedrooms oriented towards the east, and ending up with a westward orientation. Near the equator, the sun path is roughly symmetrical along the east-west axis, with the sun in the northern as well as the southern hemisphere for 6 months, depending on the inclination of the earth's axis. Since the biannual seasonal cycles correlate with the movement of the earth's axis, and the sun path almost exactly follows the equator during the hottest months of the year, no significant difference between north and south orientations exists.Therefore the latter have been omitted to reduce the number of necessary iterations.

Window Size

In Uganda, large, mirrored windows and glass doors have become popular among those who are able to afford them in recent years, as opposed by the small openings with wooden lintels in "poorer" houses whose owners cannot afford industrial materials like cement (or sometimes even fired bricks).

Since contemporary constructions almost exclusively rely on tie beams that at the same time serve as a lintel for all openings, window size is hardly restricted by constructive limitations, if the masonry is of good quality. However, brick walls are usually very thin, constructed with a stretching bond, and mortar quality is often poor, further weakening the bond. Therefore, we assume a maximum window-to-wall-ratio of 30% before the stability of the walls is compromised, decreased in steps of 10 and finally 5%, until a minimum of 5%, necessary to ensure a minimum level of adequate daylighting, is reached.

Roof Overhang

The Buildings were simulated with and without a significant roof overhang of 80 cm, at a depth of which the whole building is almost completely shaded throughout the largest part of the day. As we observed, buildings usually have a receding veranda or a wide porch with a single pitched roof along the side of the building, or little to no roof overhang, if the latter feature does not exist (yet), hence we adopted this yes-or-no approach.

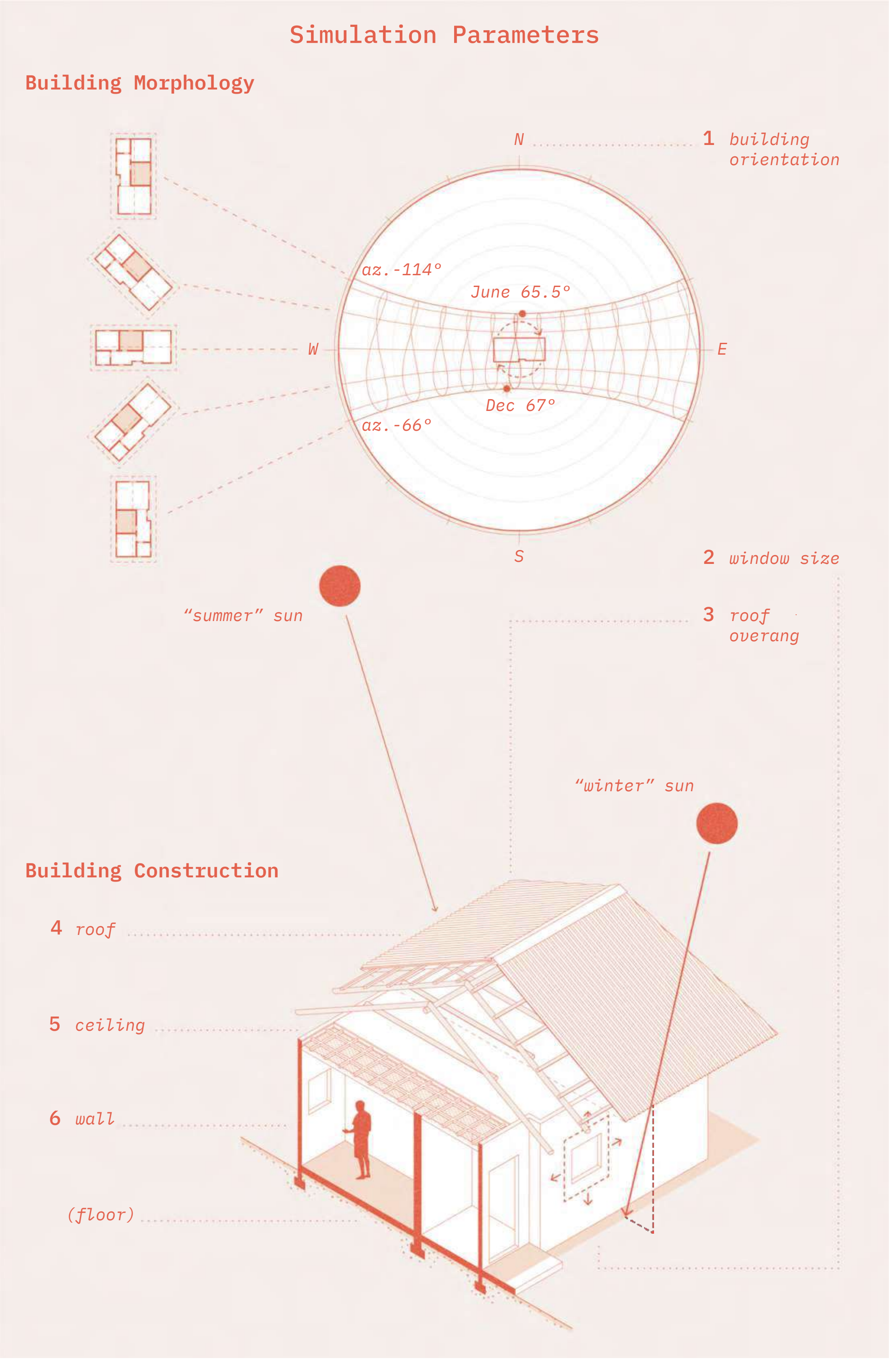
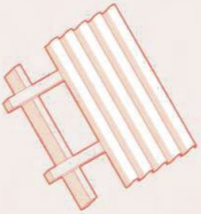


fig.3 Diagram showing the six parameters used for the building performance simulation.

Roof Construction

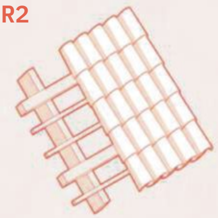
R1



Tab. 1a: *R1 - metal roof, U = 7.14 W/m²K*

Construction Layer	Thickness [cm]	Conductivity λ [W/mK]	Density ρ [kg/m³]	Spec. heat c [J/kgK]
Metal Sheathing	0.08	45.25	7824	500
Battens	5	-	-	-
Rafters	15	-	-	-

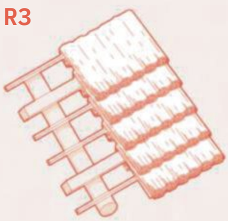
R2



Tab. 1b: *R2 - tiled roof, U = 5.88 W/m²K*

Construction Layer	Thickness [cm]	Conductivity λ [W/mK]	Density ρ [kg/m³]	Spec. heat c [J/kgK]
Ceramic Tiles	1.5	1.0	2000	800
Battens	5	-	-	-
Rafters	15	-	-	-

R3



Tab. 1c: *R3 - thatched roof, U = 0.24 W/m²K*

Construction Layer	Thickness [cm]	Conductivity λ [W/mK]	Density ρ [kg/m³]	Spec. heat c [J/kgK]
Grass Thatch	30	0.07	145	1600
Battens	5	-	-	-
Rafters	15	-	-	-

fig.4 Axonometric drawings and tables of the three roof constructions.

Roof Construction

Three different roof constructions have been chosen for the evaluation, based on material availability and vernacular building constructions existing in the area.[20] Two contemporary roof constructions that exist in this area, a metal roof (R1) that is economic but of poor thermal performance, and a ceramic roof (R2) of higher quality are complemented by a thatched roof (R3), a traditional building construction still known but hardly used for contemporary residential buildings.

(R1) is by far the most predominant construction, as ceramic roof tiles are not affordable for the largest part of the population in Uganda. As a symbol of wealth, ceramic roofs represent an idea of what a building "ideally" should look like, while thatched roofs are used only for temporary shelters or the most profane building typologies like livestock enclosures or outdoor kitchens. Fig.4 above shows all three constructions and their relevant properties.

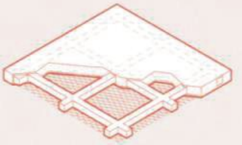
Ceiling Construction

For the ceiling construction, three different options were defined as well (fig.5). Firstly, a plastered ceiling (C1) as it is usually constructed in the parts of Uganda that we visited[21], and secondly an improved version of this ceiling, utilizing an insulation layer (C2). This layer is packed in between the initial plaster layer and a second coat of plaster on top of the construction. Our goal was to develop

Ceiling Construction

Tab. 2a: *C1 - plastered ceiling, U = 4.00 W/m²K*

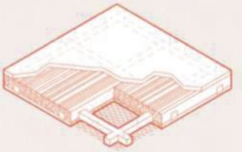
C1



Construction Layer	Thickness [cm]	Conductivity λ [W/mK]	Density ρ [kg/m³]	Spec. heat c [J/kgK]
Plaster on lathwork	4.5	0.9	1700	950
Ceiling joists	15	-	-	-

Tab. 2b: *C2 - insulated plastered ceiling, U = 0.58 W/m²K*

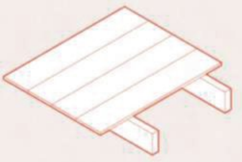
C2



Construction Layer	Thickness [cm]	Conductivity λ [W/mK]	Density ρ [kg/m³]	Spec. heat c [J/kgK]
Plaster	4.5	0.9	1700	950
Insulation	10	0.07	145	1600
Plaster on lathwork	4.5	0.9	1700	950
Ceiling joists	15	-	-	-

Tab. 2c: *C3 - Wood sided ceiling, U = 2.73 W/m²K*

C3



Construction Layer	Thickness [cm]	Conductivity λ [W/mK]	Density ρ [kg/m³]	Spec. heat c [J/kgK]
Wooden sheathing	2.54	0.15	608	950
Ceiling joists	15	-	-	-

fig.5 Axonometric drawings and tables of the three ceiling constructions.

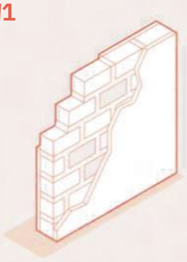
an insulated ceiling construction with natural resources available on site, like straw or reeds, and we assumed a sandwich construction with a double plaster layer of plaster would be necessary both for structural support and as a protective coating to deter vermin from entering the insulation layer. Finally, a simple ceiling that uses wooden boards or plywood sheathing to close the room towards the attic space was assumed (C3). Since the exact constructions had not been conclusively defined at the stage the simulation took place, generic properties have been chosen for the plaster and insulation layers. However, these properties should not be significantly different from those of the materials to be found in the project region and used for experiments during construction.

Wall Construction

For the exterior walls, two brick wall constructions were assumed, one with a running bond (W1), the second with a header bond (W2), and therefore of doubled mass volume. While it is relevant whether those bricks are burnt or unfired for the life cycle assessment (LCA) and evaluation in the last part of the thesis, the material properties relevant for the thermal simulation do not vary significantly in the two types of bricks. Therefore, only the thermal mass of the two building construction changes dependent on the thickness of the walls. The third simulated wall construction (W3) is a wattle-and-daub wall with organic aggregates (a lathwork from twigs and reeds, filled and plastered with a mixture of clay and plant fibre

Wall Construction

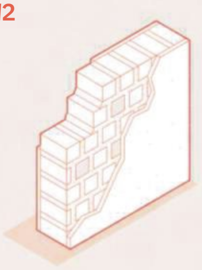
W1



Tab. 1a: *W1 - brick wall thin, U = 2.30 W/m^2K*

Construction Layer	Thickness [cm]	Conductivity λ [W/mK]	Density ρ [kg/m^3]	Spec. heat c [J/kgK]
Int. Plaster	4.5	0.9	1700	950
Clay Brick	15	0.8	1800	790
Ext. Plaster	2.5	0.9	1700	950

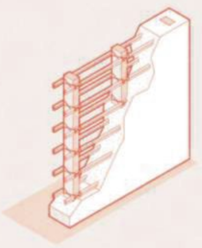
W2



Tab. 1b: *W2 - brick wall strong, U = 1.60 W/m^2K*

Construction Layer	Thickness [cm]	Conductivity λ [W/mK]	Density ρ [kg/m^3]	Spec. heat c [J/kgK]
Int. Plaster	4.5	0.9	1700	950
Clay Brick	30	0.8	1800	790
Ext. Plaster	2.5	0.9	1700	950

W3

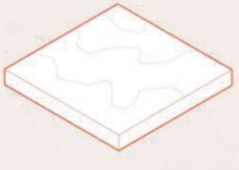


Tab. 1c: *W3 - wattle-and-daub wall, U = 1.18 W/m^2K*

Construction Layer	Thickness [cm]	Conductivity λ [W/mK]	Density ρ [kg/m^3]	Spec. heat c [J/kgK]
Int. Plaster	4.5	0.9	1700	950
wattle-and-daub wall	15	0.25	800	700
Ext. Plaster	2.5	0.9	1700	950

Floor Construction

F0



Tab. 1c: *F0 - generic massive floor, U = 2.4 W/m^2K*

Construction Layer	Thickness [cm]	Conductivity λ [W/mK]	Density ρ [kg/m^3]	Spec. heat c [J/kgK]
generic slab	20	0.8	2000	930

fig.6 Axonometric drawings and tables of the three wall constructions and a generic floor slab.
fig.7 (next page) Piles of construction materials in front of residental buildings between Wobulenzi and Luwero.

additives), improving the thermal properties of the building component as compared to the first two constructions. For the interior walls, (W2) was assumed for all iterations for structural reasons. The three constructions and their properties are shown in fig.6.

Floor Construction

Several different floor constructions were tested on site[22] and included in the final evaluation of the project, at the early design stage however, no floor construction had been defined yet. Therefore, the same generic massive floor slab (F0) was used as a placeholder in all iterations (fig.6). The properties of this floor slab are consistent with those of the concrete floors usually realized in small-scale residential buildings in the area. Additionally, the final evaluation shows that the average properties of all floors tested and finalized on site do not vary significantly from the ones assumed for the simulations.

Results

While the final geometry of the buildings constructed on site does not vary significantly from the volumetric model used for the simulations, the composition and exact materiality of the different building components had not been fully defined at the time the simulation was conducted. As the use of different potential resources was part of the construction process and the related experiments with building components on site, a certain vagueness and lack of definition were an almost essential part of our planning process. Therefore, the simulation results do not exactly represent the buildings on site while still providing a valid approximation of the actual situation. In a certain way, we believe that this fact, rather than representing a limitation, makes our findings more generally applicable.

As stated above, after running the simulations, results are evaluated by taking two indicators into account: monthly average maximum operative temperatures, and adaptive thermal comfort metrics, namely the amount of time that indoor conditions are above the 80% acceptability limits and the building is overheated, are compared. All results from all 1080 iterations are regrouped six times to present the results as a function of each parameter and its respective variants once, which helps to visualize the magnitude of influence of each parameter on overall building performance.

Maximum operative temperature

The six graphs with the average maximum operative temperature curves derived from all possible iterations for each respective parameter (fig.7) already illustrate the influence of each parameter on the thermal performance of the building.

If the average difference between the best (i.e. the one with the lowest maximum temperatures) and worst-performing variant of the respective parameter is large, the parameter has a large influence on the thermal performance of the building. If the difference between the averages is low, so is the influence of the parameter on indoor thermal comfort, and, statistically, no significant improvements inbuilding performance can be expected by changing this parameter.

All temperature graphs show a similar shape, a double wave with two temperature peaks in March and October, which correlates to maximum outdoor temperatures, but with sometimes significant differences of up to 3.3°C between variants for March, the hottest month of the year, which is most relevant for the discussion of the results. When monthly mean maximum operative temperature is discussed, for the rest of the chapter it refers to this monthly value.

While operative temperature is a relatively good indicator to make the differences in thermal performance of a building and its respective parameters more tangible by linking it to the readers' own physical experience of temperature perceptions, it does not yet adequately depict thermal comfort. As it is only refers to a single value from one specific daily timestep, the dimension of time is missing in these results altogether. It is not clear how often and for how long these maximum values are reached, and for which period of time slightly lower values that may still be a cause for thermal discomfort or heat stress prevail throughout the year.


FOR CONCRETE
PRODUCTS


MT. OLIVES
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Percent of time overheated

When evaluating a room, it makes a large difference whether it is overheated for a short while on hot days, or over an extended period of time that significantly restricts liveability. Adaptive thermal comfort statistics provide this insight into the overall performance of an indoor space throughout the year. The scatter-plot in fig.8 shows the distribution of all results for the 1080 iterations. Along the x axis, the percentage of time during which the buildings overheat is plotted against the frequency of occurrence of a certain result – grouped into 0.1% intervals – along the y axis. Again, results are evaluated as a function of each individual parameter, and six graphs – one for each parameter – are juxtaposed.

Of all 1080 iterations, 380 buildings, which equates to 35% of the total number, perform well without overheating (below 0.1 % of time overheated). In each scatter plot, the number of variants without overheating have been included in the top left corner of the graph, the scale of which is limited to the much narrower range in which the other results are distributed in terms of frequency of occurrence. Interpreting the graphs, the first important value is the mean value of time overheated for each parameter variant. The larger the difference between the lowest mean value (corresponding to the best-performing parameter variant) is to the highest value (i.e. the worst-performing parameter variant), the larger the influence of the parameter on indoor thermal comfort. Correspondingly, the narrower all data points for a certain variant are scattered along the x axis, the more significant is its influence. In the next paragraphs, the results for each individual parameter will be discussed shortly.

Orientation

With mean maximum monthly operative temperatures ranging from 26.9°C for a northwards orientation to 27.9°C for a westwards orientation, this parameter has a noticeable, but not the largest influence on indoor temperatures. Regarding thermal comfort, on average, rooms overheat between 2.3% and 3.7% of time throughout the year, and results for all variants are scattered relatively widely among the x axis, which means the significance of the parameters influence is not as high as that of other parameters. Therefore, a northward (or southward) room orientation is favorable over an orientation towards the east or, especially, west, if possible. However, if geographical or other constraints on the building site limit the constructible surface, adverse effects from a less than optimal building orientation can be compensated for by other design measures.

Roof Overhang

The maximum difference between mean maximum operative temperatures for buildings with and without roof overhang lies at only 0.6 °C, with mean maximum operative temperatures ranging between 22.1°C and 27.7°C. Total time overheated lies in a similar range as building orientation, between 2.4% and 3.7%. The average influence of the roof overhang on indoor thermal comfort is relatively small, but it can help to improve the performance of glazed windows by shading them from direct solar irradiation.

Window Size

The parameter of window size was defined as a function of exterior wall area. Within the chosen simulation framework, window size has the largest influence on both mean maximum operative temperatures and time overheated, with mean maximum monthly temperatures ranging from 26.0°C to 29.3°C, and time overheated ranging from 1.2% to 6.1%. However, this can be partly attributed to the wide range of glazing ratios chosen for the simulation, ranging from 5% to 30% of the external wall area. When only the glazing ratios of 10% and 20% are compared, which based on our observations in Uganda represents a more realistic range for this specific building type, the temperature difference is only 1.4°C, and the time overheated at 1.5 % and 3.2%. Additionally, it is difficult to evaluate the performance of windows isolated from the first two parameters, orientation and roof overhang.When further broken down, it can be seen that for windows facing north or south, window size ratio is much less relevant for the overall thermal comfort performance of the building.

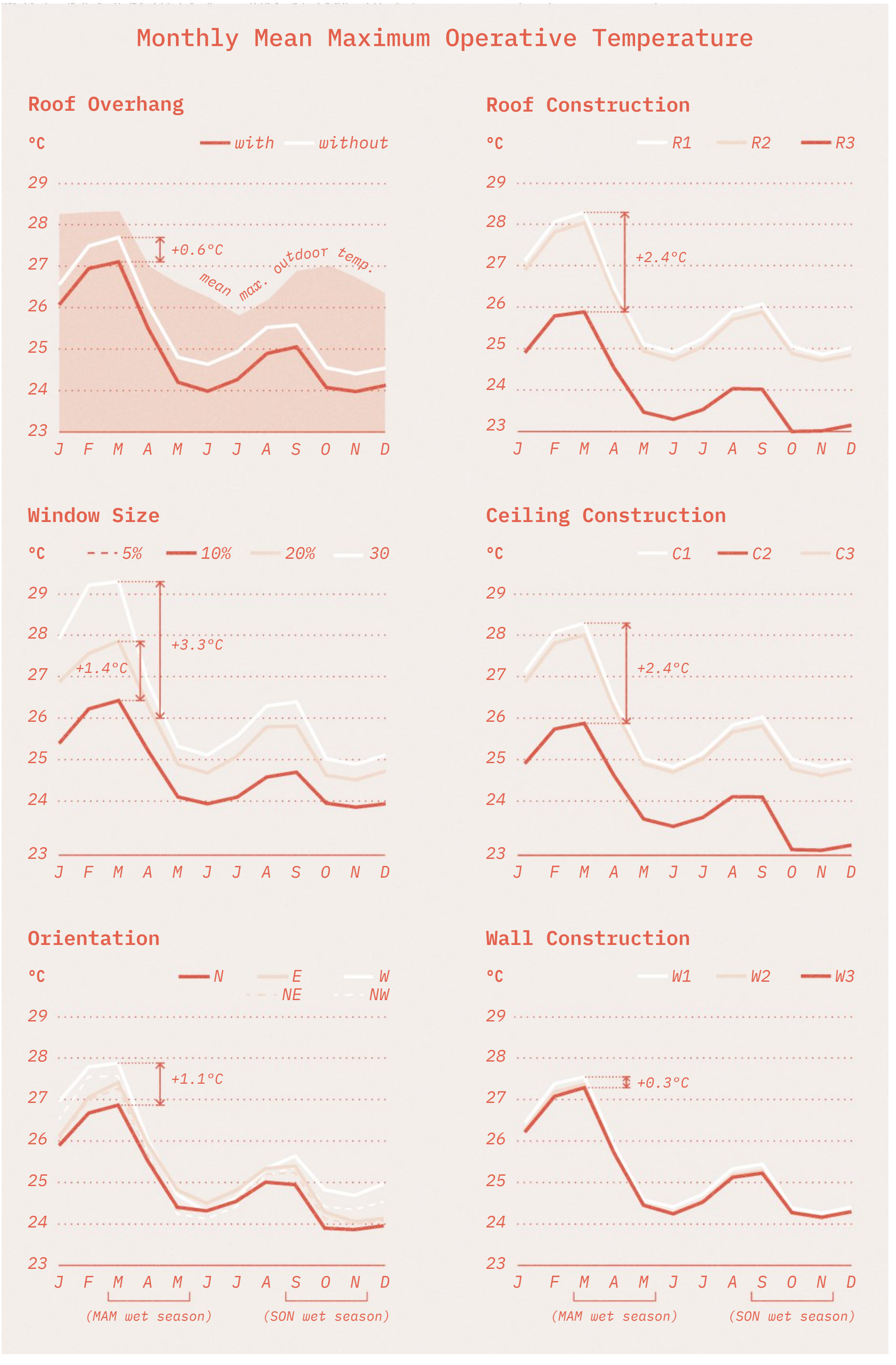
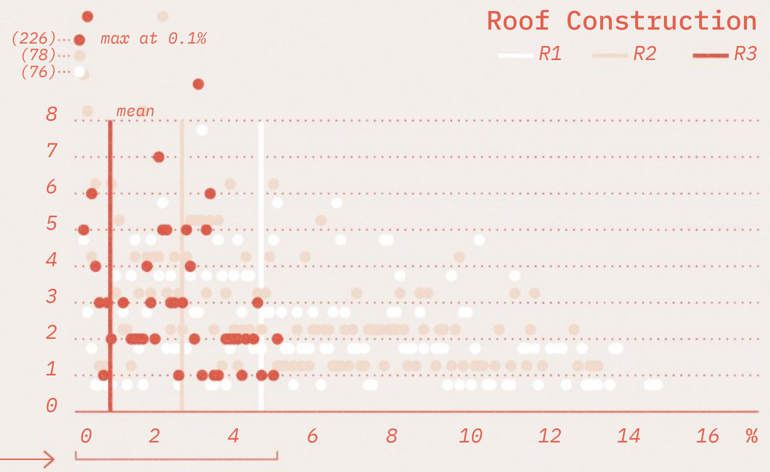
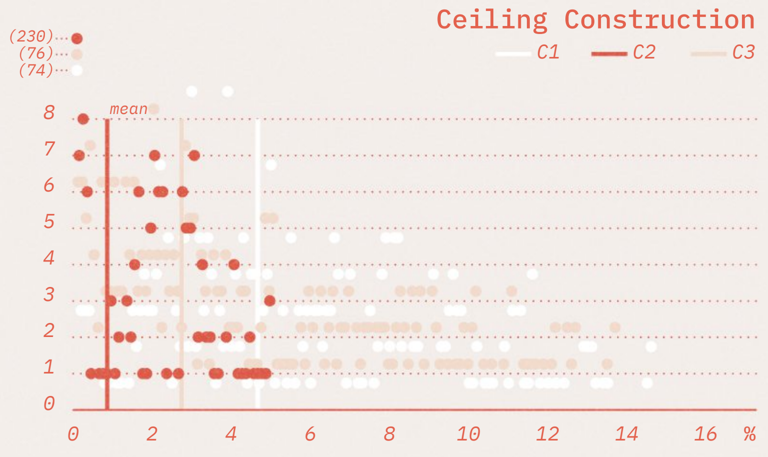


fig.8 Monthly mean maximum operative temperatures as a function of the different simulation parameters.

fig.9 Scatterplots of the distribution of adaptive comfort metrics as a function of the different simulation parameters.

A narrow range of data points on the left side of the graph signifies a large positive influence of a specific variant on indoor thermal comfort.





A wide distribution of all data points means that a parameter has no significant influence on improving indoor thermal comfort. This is also reflected in the similar mean values.

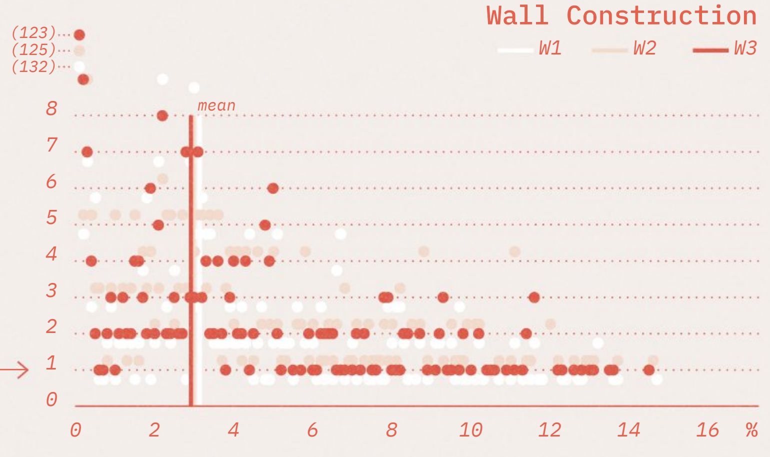


fig.10 (right page) A corridor at Hotel Networth.

Roof Construction

Not surprisingly, the roof construction has, along with ceiling construction, the largest influence on indoor thermal comfort. Mean maximum monthly operative temperatures range from 25.9°C to 28.3°C, and average time overheated from 0.9% to 4.6%. The metal roof (R1) performs very poorly, and results for the ceramic roof (R2) are just slightly better. Since both building components do not contribute significantly to indoor thermal comfort, results for time overheated are scattered widely within a range from 0 to almost 15%. Only the thatched roof (R3), the traditional roof construction used in historic vernacular buildings, performs well, and is most suited to the tropical climate with its high solar irradiation.

Correspondingly, due to its large positive influence on building performance, results for time overheated are scattered narrowly between 0 and 5.1%. This means that changing this component would be the most effective measure to improve indoor thermal comfort in comparable buildings. As there is a cultural aversion against thatched roofs as an everything but obsolete material with an air of poverty and backwardness[23], it could be hard to convince any local builder or homeowner to use this kind of construction, especially when combined with the perceived short lifespan and high maintenance effort associated with it.

Ceiling Construction

The different ceiling constructions perform almost in the same way as the roof constructions. Mean maximum monthly operative temperatures range from 25.9°C to 28.3°C, and average time overheated from 0.8% to 4.6%. As thatched roofs are snubbed upon, improving the thermal performance of ceilings is the most promising measure to effectively improve building performance by changing only a single parameter. The installation of an insulated ceiling can effectively mitigate the adverse effects of a metal roof. In addition to providing thermal insulation for the interior rooms, it also serves to insulate the building from external noise, such as the reverberations of heavy rainfall on the roof. Furthermore, it does not affect the visual appearance of the building, which may enhance its cultural acceptance. Given that ceilings can be protected from decay caused by pests and weather conditions, natural materials can be used more efficiently.

Wall Construction

Different wall constructions barely have an effect on thermal comfort. With a difference of only 0.3°C in mean maximum monthly operative temperatures and average time overheated ranging between 2.9 and 3.2%, the influence is almost negligible. Two main reasons constitute this fact: firstly, the available economically feasible constructions do not differ greatly regarding their thermal properties like U-values or thermal mass and secondly, when there is no direct solar irradiation on a building component, due to the high humidity of the tropical environment, constant cross-ventilation and low variations between maximum and minimum daily temperatures, thermal resistance of a building component does not play a significant role, as indoor air temperatures will always approximate outdoor conditions due to constant air exchange. In the same way, the thermal mass of a building has, if anything, an adverse rather than a positive effect under these climatic conditions.

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18 ASHRAE (2013) p. 12.
19 Thornton Tomasetti's CORE Studio (2016) *Colibri, Version 2.0.0* [Computer Software]. New York: Thornton Tomasetti.
20 Weidacher, M. (2024) *For Example Bowa Hill - On the Transformation of Contemporary Vernacular Architecture: Building Culture and Materials,* pp. 62-92. Vienna: Vienna University of Technology.
21 Ibid., pp. 148-210.
22 Ibid.
23 Ibid., p.222, p.256.

Design
Plans for Bowa Hill

Benedikt Mass / Maximilian Weidacher

The planning task marks a turning point in the thesis project. While most parts of the previous research and the pre-design assessments can be solely attributed to what we consider as common assertions, the engagement with Bowa Hill is coupled with site- and project-specific considerations and decisions. As the plans have to account for both, the general and the specific, one of the biggest challenges is to negotiate between the two. The chapter begins with history of Bowa Hill and the project brief. Outlining the plans for a centre for sustainable agriculture, we will then discuss the spatial organisation of the property and the settlement structure, followed by a description of the case study buildings.

About Bowa Hill

In 2016, longtime friends and future business partners Paul Senoga and David Vogt drive to a village called Kimwanyi in the south of Nakaseke District. For some time, the two have been looking for an affordable piece of arable land, ideally not too far from Kampala. Although the distance between Kimwanyi and Kampala is only 60 km, the trip takes between 2 to 6 hours, depending on traffic and weather conditions. The first part of the journey to Wobulenzi follows the paved Kampala-Gulu highway, a national thoroughfare characterized by traffic jams and small roadside stalls, shops and markets. Nail clippers, a haircut, fruits and vegetables, upholstery, windows and doors, pesticides, sacks of flour, wedding dresses... There is not much you can't get on the side of the road.

Wobulenzi is halfway between Kampala and Luwero. Directly linked to two cities, it is an important regional hub with schools and training centers, doctors and clinics, markets and shopping streets, guesthouses and hotels. At the northern end of Wobulenzi, you leave the highway and turn off onto a dirt road towards the small town of Nakaseke. The round asphalt edge marks the boundary between two worlds, the (peri-)urban and the countryside. From here, it is another 25km or 30-40 minutes to Kimwanyi. As the dirt road to Nakaseke winds up and down through swamps and fields, houses cluster in roadside villages, then scatter again across the wide, hilly landscape. Just before entering Nakaseke, you turn left - from

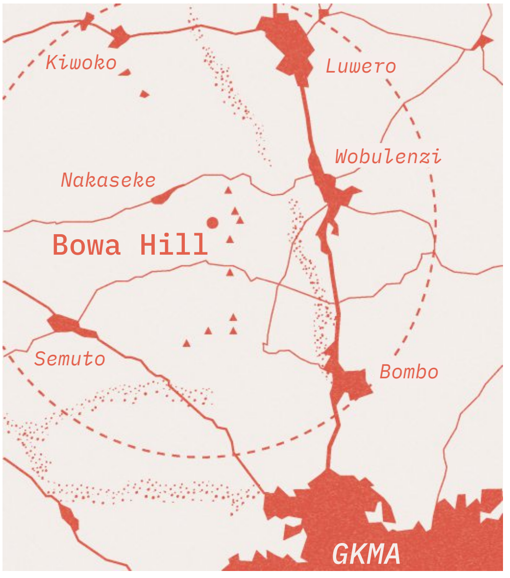


fig.1 Towns and road network in the project region. The dashed line indicates the local scope, i.e. a 20km radius around Bowa Hill.

it's another 9km to Kimwanyi. Along with the village road, the homesteads get smaller and smaller. Often only the facade facing the road is plastered, or, as in most cases, none at all. After a short drive you reach the village of Kimwanyi. At a small corner shop a washed-out path branches off. From here it's another 15 minutes walking to Bowa Hill. It is a path typical of the region, at the end of a hierarchy and an expression of the relationship between town and country.

Its remote location, with no direct access to the local road network, steep terrain and poor soil make Bowa Hill unattractive for common

fig.2 Satellite image of the Bowa Hill and it's surroundings.


Bowa Hill
Kimwanyi
200m

uses such as homesteads or plantations. Despite the low price, no buyer had been found for many years. Until, long story short, Paul, Lisa and David decide to buy the 4-hectare barren property.

To make the soil more fertile, they offered free farmland to local farmers under the condition of a diversified cultivation with frequent crop rotation and no use of chemical pesticides. In return, the farmers look after the property and the roughly 600 newly planted fruit trees. For the time being, no permanent infrastructure is being built. As years pass, ideas for a model farm as a local center for sustainable agriculture grow. Then, 2019 and the Covid pandemic arrive.

Project Brief

In autumn 2020, at a time of general uncertainty, we began working with Paul, Lisa and David on a strategy for the future of Bowa Hill. In regular meetings we condensed ideas, references and doubts. The following project brief summarizes the key elements and planning principles we have agreed on.

- Home: a house for a family (4-6 people) living permanently on site; "Western standard" kitchen and bathroom in the house; a second, smaller house for 2 farm workers or volunteers; capability for incremental growth for future development.
- Community: a communal kitchen with dining area; a covered outdoor area for communal activities and group training; a kitchen garden in proximity.
- Work: a garage/workshop building to store tools and a vehicle; a covered area for outdoor work. The building should be easily lockable and within sight of the residential buildings (no storage facilities for agricultural products required).
- Infrastructure: an off-grid infrastructure concept that includes power and water supply as well as wastewater management.
- Road/ Paths: a road ideally up to the residential buildings; a network of paths for agricultural work.
- Agriculture: a tree nursery with access to water; designate space for arable land.

All interventions should take up as little space as possible. Existing trees should be preserved. Nature always has priority.

Organizing and Interpreting

The name Bowa Hill derives from the property's morphology. The hill is part of one of the countless chains of hills that characterise the landscape of the Central Region of Uganda.[1] Typical of the region, almost all the neighbors live from small-scale, self-sufficient or partially self-sufficient agriculture. The only exception is a small eucalyptus plantation to the southwest. The property is trapezoidal in shape and measures approximately 4 hectares. A ridge, running from east to west, divides the hill into a larger southern half and a smaller northern half. Two thirds of the southern half is steep terrain, the upper third below the hilltop forms a plateau. The northern half starts off steep but becomes flatter as it descends. There are around 600 trees on the property, most of which are young fruit trees. Bowa Hill's diverse vegetation is home to a variety of birds and other wildlife.

The proposed organisation of Bowa Hill is based on the natural division into 2 halves. The southern half is essentially reserved for nature and agriculture. The road for vehicle access and the well near the entrance at the south end are the only built structures on this side. The road runs along the flatter western boundary, past the tree nursery and the intensively farmed high plateau, ending at the building site in the northern half. The road layout allows for the possibility of an extension to a potential second access via a neighboring property to the north. On the eastern perimeter of the property, a steep and direct footpath connects the building site to the entrance in the south. From east to west, following the topography, a series of paths connect the two access routes. The network of paths essentially reflects ways that have been established naturally over the years of agricultural cultivation.

The location of the building site at the foot of the steep slope in the northern half is a compromise between keeping fertile, easily arable land free and minimising the amount of groundwork. A cistern above the building

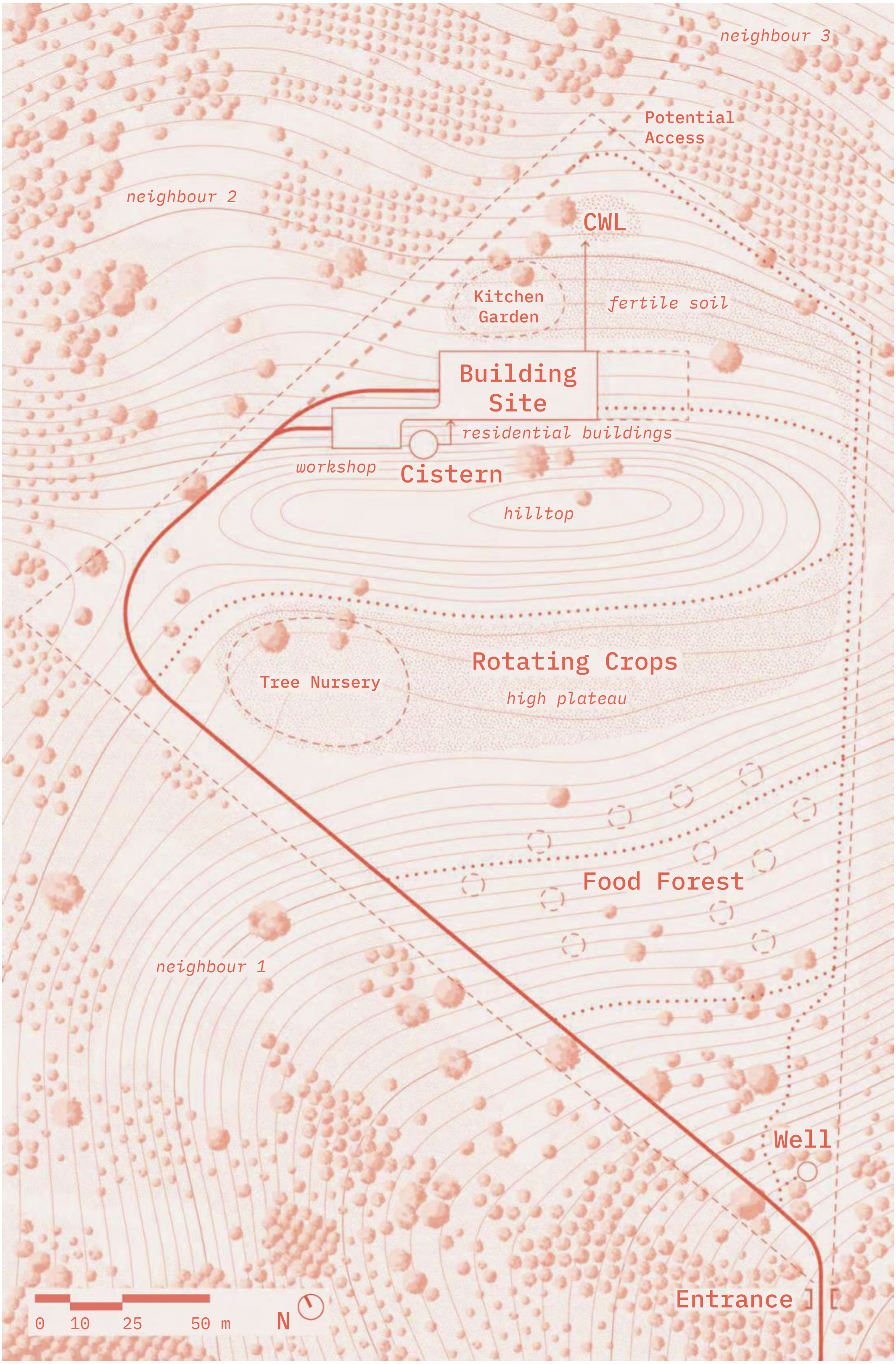


fig.3 Schematic drawing of existing elements and the programmatic organisation of Bowa Hill.

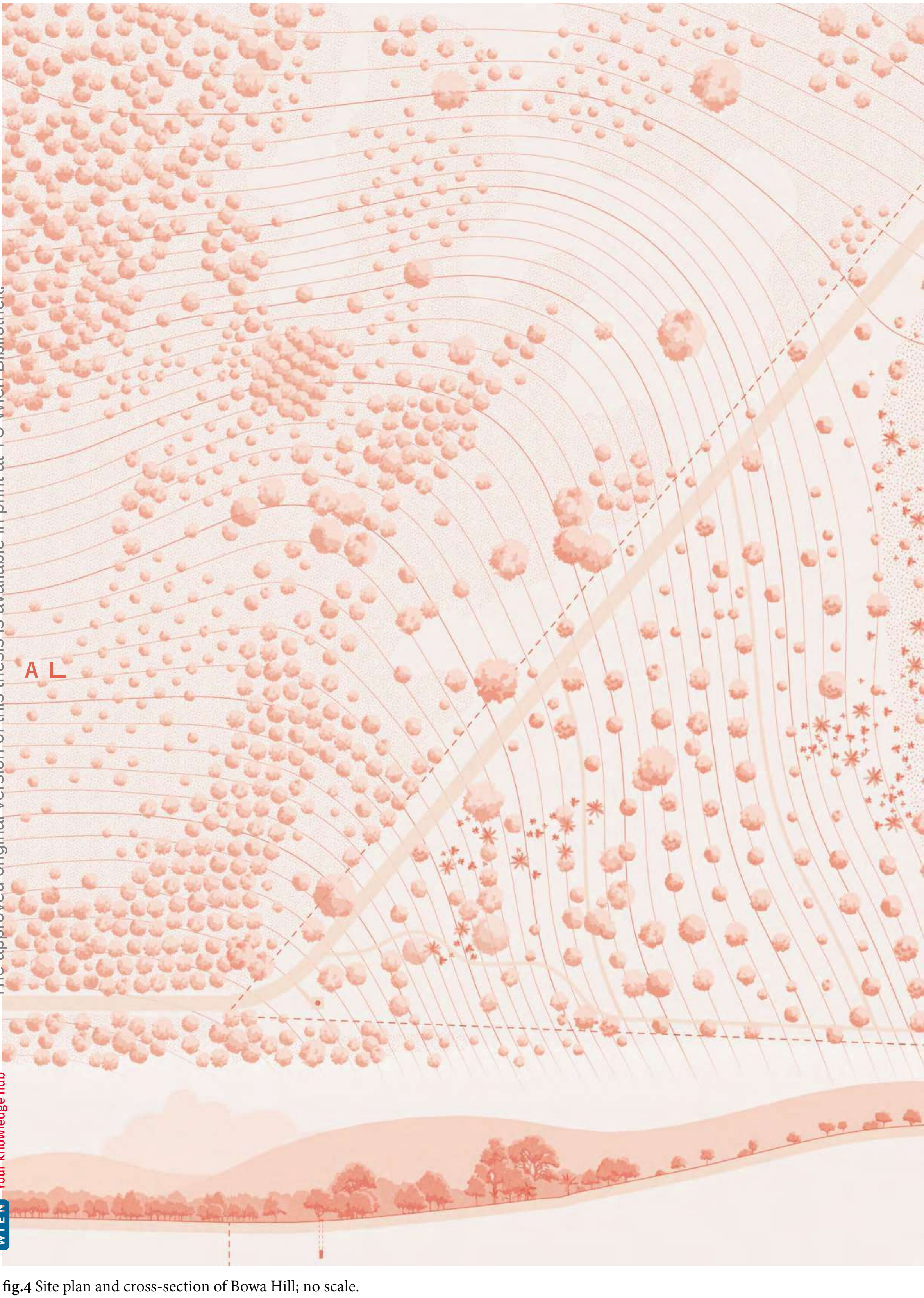


fig.4 Site plan and cross-section of Bowa Hill; no scale.


A
0 5 10 20 50 m
N

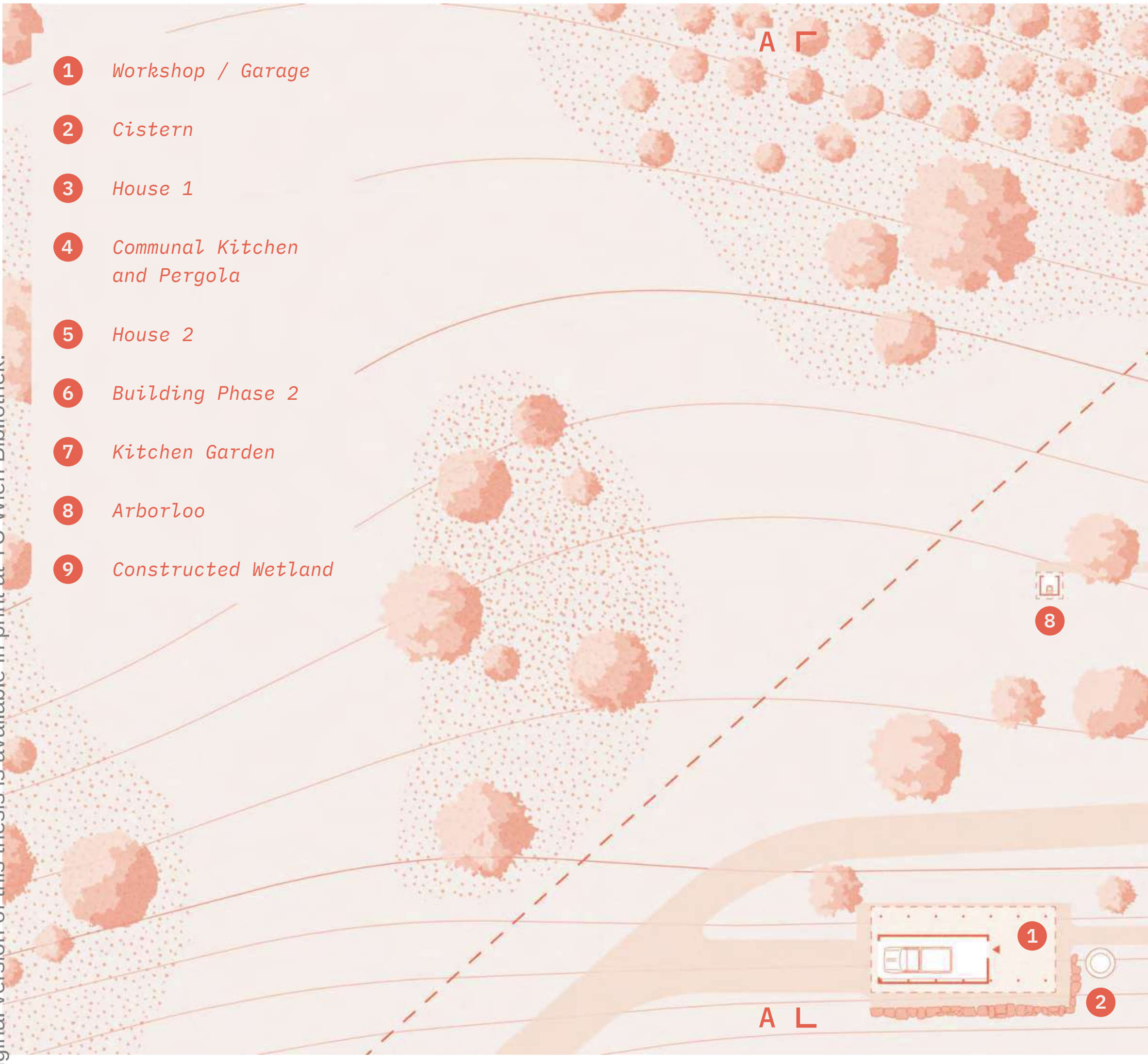


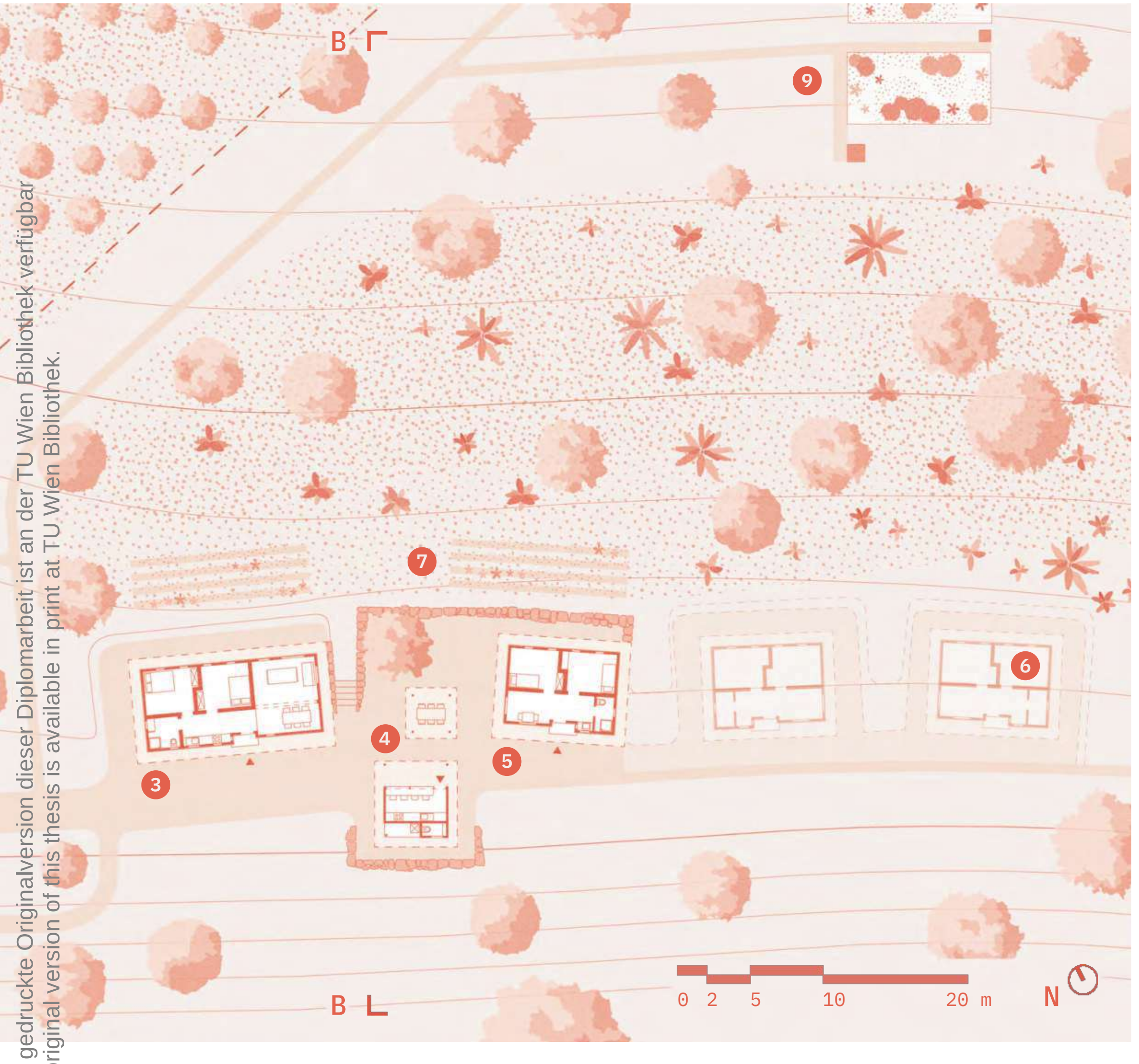
fig.5 Homestead Layout; 1:500. The drawing shows the main elements and layout of the building site.

site supplies the buildings with fresh water. All waste water is treated in a constructed wetland in the north of the property.

Homestead Layout

As noted above, the immediate surroundings, like most of the Central Region of Uganda, are characterised by small homesteads. It seemed obvious to us to follow these regional customs in terms of both structure and scale.

From a pragmatic point of view, the plateau in the southern half meets the basic requirements for a building site. The plateau faces the village road (which facilitates transport), the terrain is relatively flat and the high elevation guarantees sufficient air movement on hot days. However, there are 2 arguments against this location. Spatially, the relationship between above and below is often a reflection of hierarchy. In most cases, as the entrance is on the south side, the plateau is approached from below. Regardless of the architectural form, the location would imply a superior, defensive character. The second argument relates to conflicting interests between building and farming. The flat terrain of the plateau not only makes for good building land, it is also the most arable land on the predominantly steep southern half of the hill. Although the steeper site in the northern half initially requires some adaptation of the



terrain, it preserves fertile land for vegetation and agriculture. As the road now descends towards the buildings, the relationship with the surroundings is no longer one-sided but rather ambiguous. In a dissolution of the hierarchical order, the settlements location in the north is both "below" and "above".

The first thing you see as you cross the hilltop is the roof of the workshop/garage building. Beyond is a vast, rolling landscape. The roof of the building is supported by a grid of columns and houses an enclosed volume and an open work area. Both the road and a direct footpath lead down to the residential buildings, which are located about 3 meters lower. The homestead has a linear structure and runs from east to west, following the direction of the terrain. All buildings have only one floor. Between the larger House 1 and the smaller House 2 is a communal area with a small pergola and palaver tree for shade. The 'public' rooms of the houses face the square to the east and west, while the bathrooms are positioned away from it. To the south, the square is bordered by a communal kitchen with a toilet and an open laundry at the rear. A stairway connects the residential buildings with the kitchen garden below. The linear structure of the homestead allows the development to be extended to the east in a second phase if required.

fig.6 Residential buildings; 1:200. From left to right: House 1, communal kitchen and pergola, House 2, building phase 2.


0 1 2 5 10 m
N

fig.7 Elevation west (AA); 1:200. From left to right: fields, kitchen garden, arborloo, residential buildings, workshop/garage.

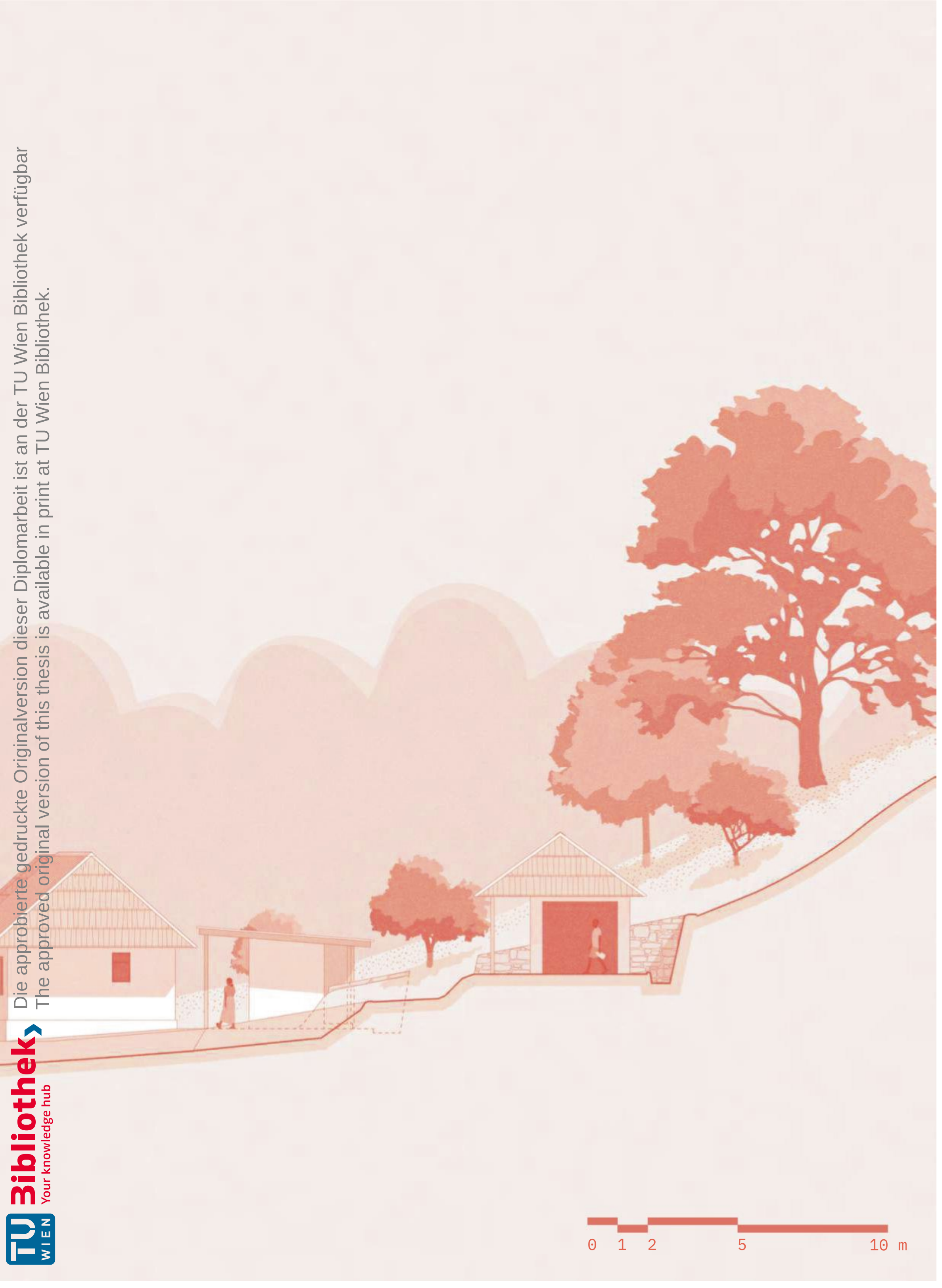
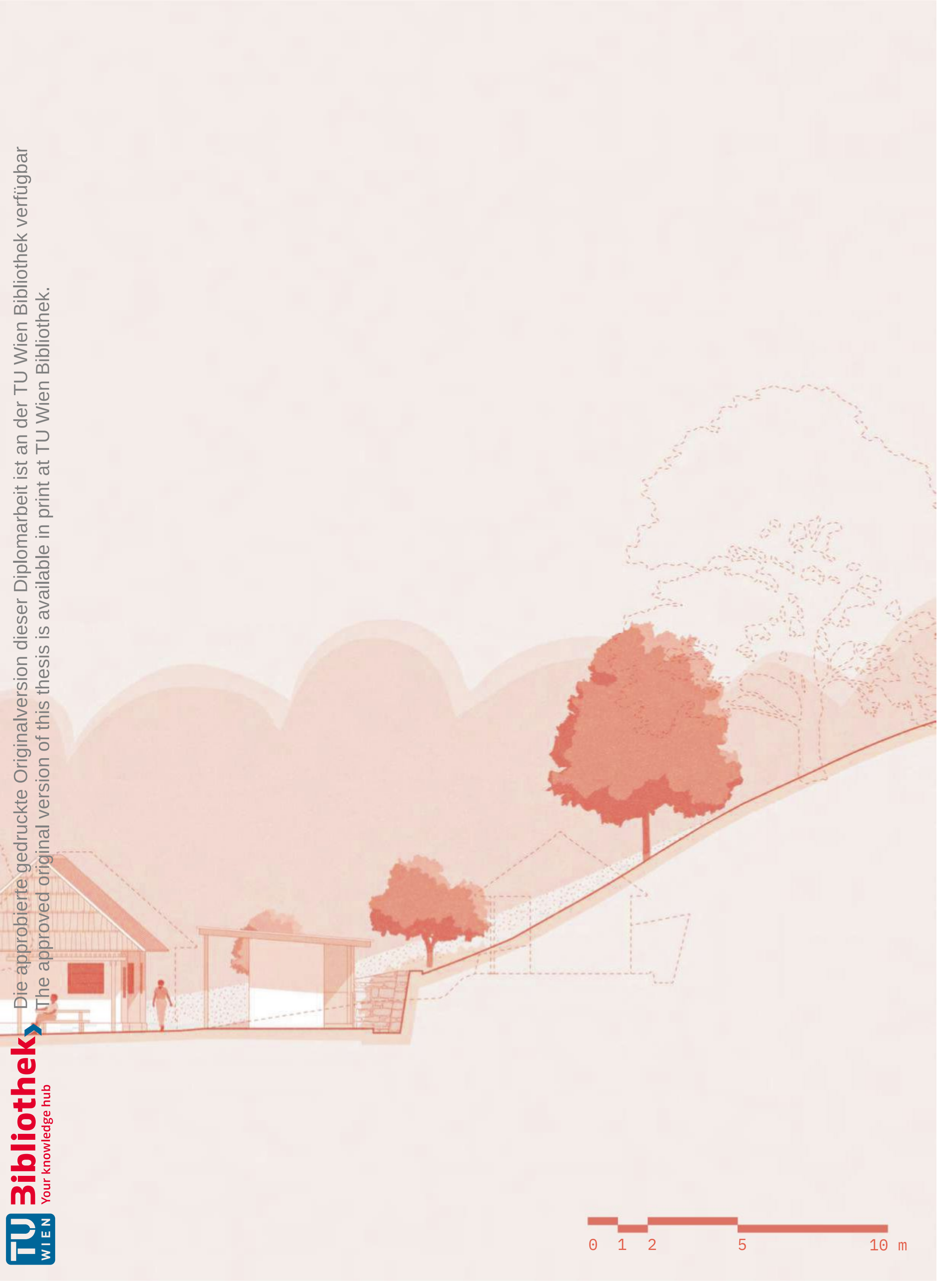

0 1 2 5 10 m

fig.8 Section / elevation west (BB), 1:200. From left to right: fields, kitchen garden, residential buildings.


0 1 2 5 10 m

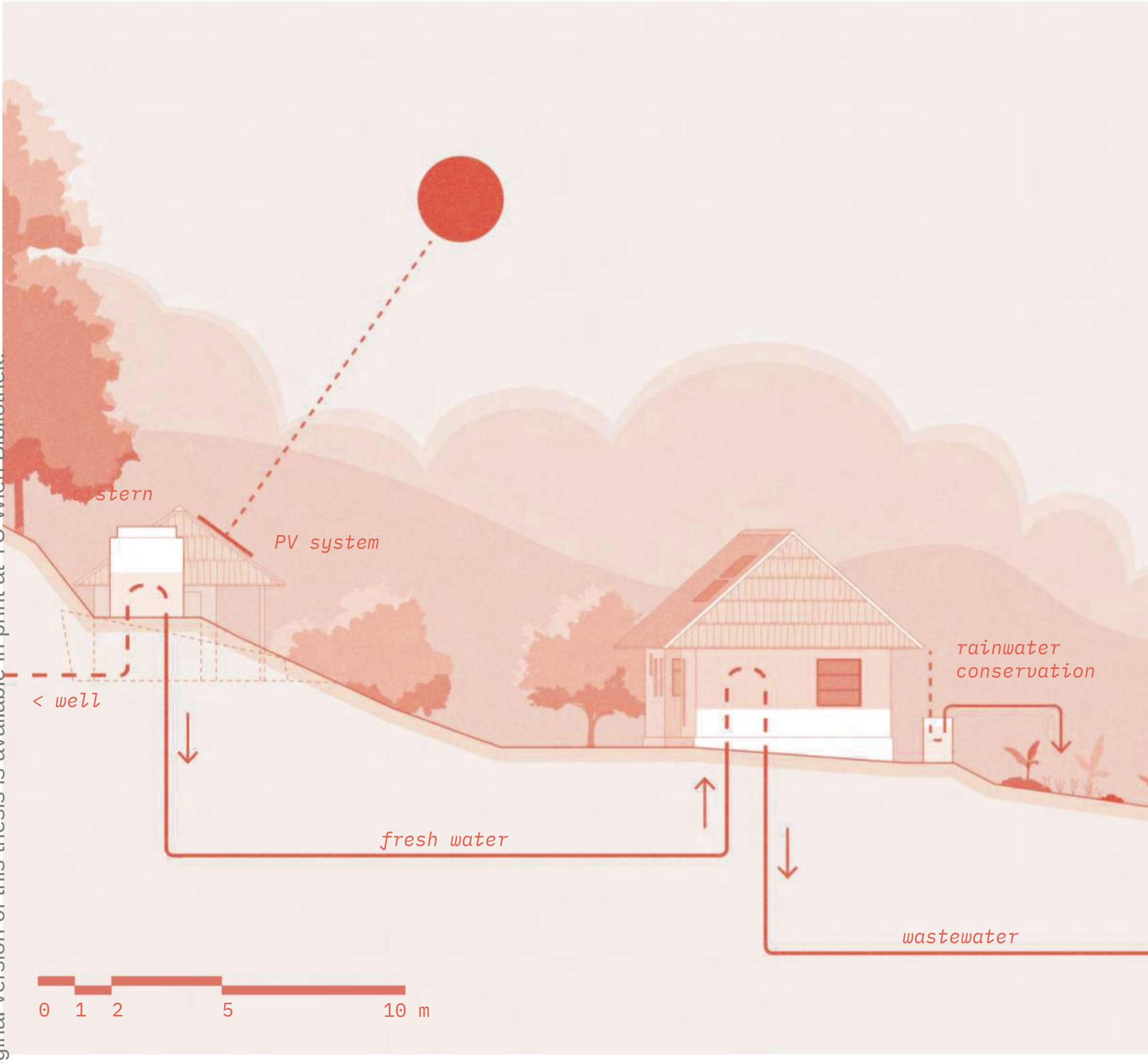


fig.9 Off-grid infrastructure scheme. On the left: water and power supply; on the right: wastewater treatment.

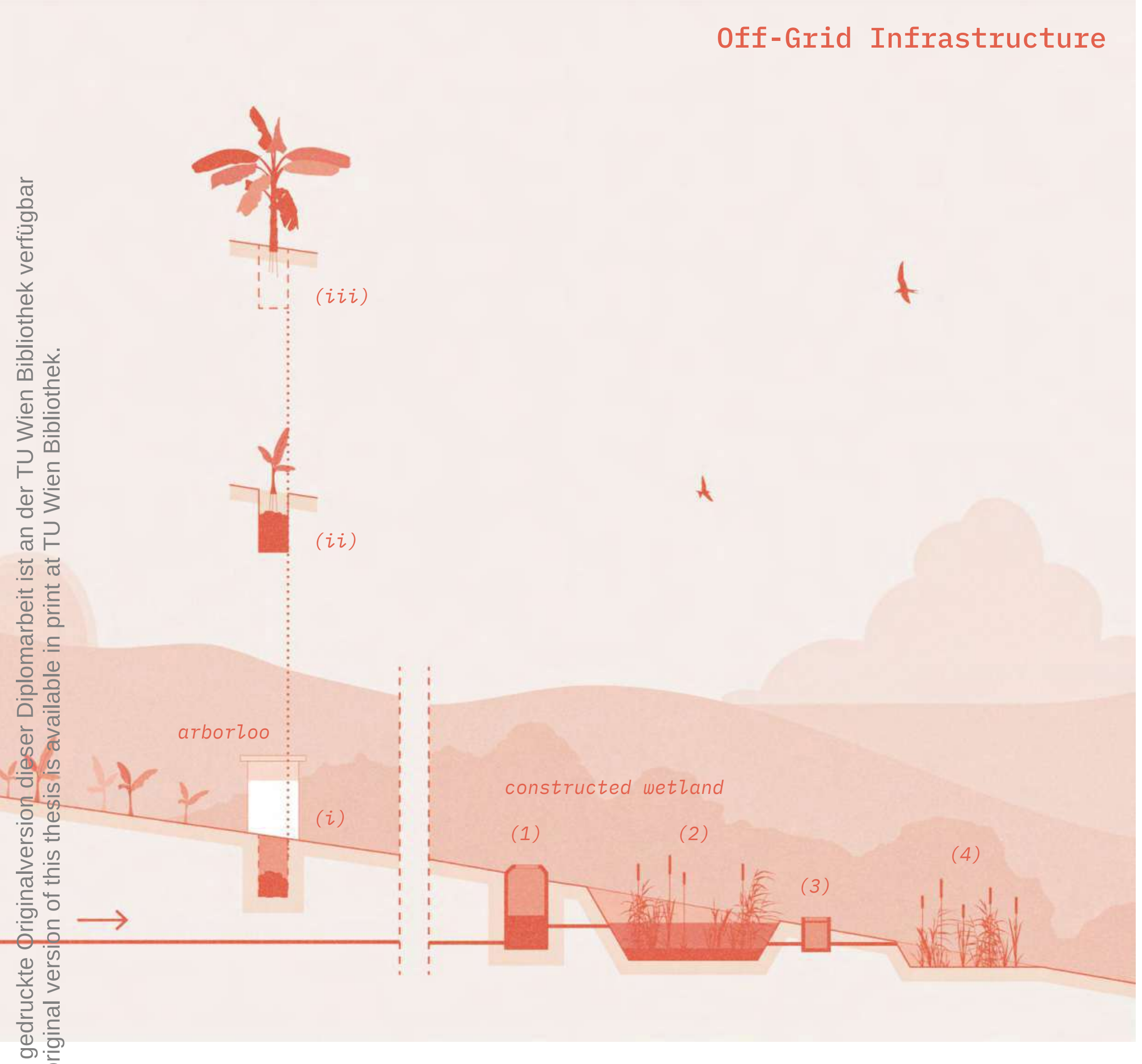
Off-Grid Infrastructure

In the case of Bowa Hill, the closest power line passes through Nakaseke, and the nearest sewer may be in Wobulenzi, if not further. As for most of the country, there is no alternative to off-grid infrastructure.

Small-scale photovoltaics (PV) are widespread in rural Uganda. The high position of the sun and the many hours of sunshine make solar power a reliable source of electricity. At Bowa Hill, all buildings are equipped with a PV module that provides electricity for the lighting in the evenings and for charging mobile phones and other battery-powered devices. The largest energy consumer is a stand-alone solar fridge in the communal kitchen. As an alternative to the problematic use of wood, all stoves operate on propane cylinders.

Regarding water management, our aim was to design a circular system within the boundaries of the property. To start with, it is important to understand, that not only does the hill divide the property into two halves, it also acts as a natural watershed. Furthermore, the topography suggests a natural flow of water.

The cycle starts with a 17 meter deep well near the entrance on the south side of the watershed. During daytime a solar-powered submersible pump brings water from the well to the cistern on the other side of the hill. The



cistern supplies water to the tree nursery and the residential buildings. Drinking water is purified by a direct-flow filtration system in the communal kitchen. Rainwater is collected from all roofs to irrigate the kitchen garden and other sensitive crops during the dry season.

For the duration of construction and until a permanent system is in place, an arborloo is installed. In a first phase, feces are collected in a shallow, dry pit (i). When the toilet is no longer needed, the pit is filled with soil and a tree is planted (ii). Over time, microorganisms cause a gradual decomposition of the fecal matter, allowing for the extraction of nutrients by the roots of the tree (iii). The constructed wetland (CWL), the end of the water cycle, is located on the northern side of the watershed. The treatment process starts with the separation of solids from fluids (1). The solids are collected in containers and can be used as natural fertiliser in agriculture. Fluids enter the first basin (2) via an overflow. In a natural process, microbes convert the potentially pathogenic human waste into nutrients for the plants in the CWL. Through a second shaft (3), which serves as a control point for taking water samples, the wastewater reaches a second basin (4) where it is further purified. To further minimise the risk of contamination, the basins are kept well above the water table.

fig.10 Elevation north; 1:200. From left to right: House 2, community kitchen and pergola, House 1, cistern, workshop/garage.

The Buildings

With the design of the buildings, we return to our reflections on the contemporary vernacular typology and the common practices. As an expression of what we referred to earlier as the essential "lack of definition" in planning[1], the design decisions that will be discussed mainly concern the shell of the building. The chosen graphical representation of the plan drawings (fig. 11) is an attempt to capture both what is planned and what has not yet been decided. Additionally, we have included a supplementary scale of brick count to provide a measure of the expected level of accuracy in implementation. Since the outbuildings are of limited importance to the research, we have decided to exclude a more detailed presentation. Representative of both residential buildings, the following description refers to House 2. The designations in brackets (XY) refer to the components of the pre-design.[3]

House 2

From the outside, the building appears as a low, narrow structure. The building site's topography allows for the preferable north-south orientation. Like the contemporary vernacular typology, the building has a horizontal disposition and is made up of three layers. The first layer is the foundation, which is raised as a plinth. Next follows the second layer, the slender brickwork of the outer walls. The overall appearance is much affected by the third and final layer, a large hipped roof that forms about half of the building.

With a few exceptions, the facade is characterized by narrow, vertically displaced openings of varying sizes. To prevent overheating from the low position of the sun in the morning and afternoon, most of the windows are oriented to the north and south. To prevent excessive direct solar irradiation, the building is shaded for a large part of the day by a 2ft (60cm) roof overhang. External shading elements or vegetation can be added to provide shade to the east and west if required. As mentioned in the previous chapter, consistent cross-ventilation has a significant impact on the thermal comfort of buildings in tropical climates.[4] To provide the best possible ventilation of the interior, each opening has an opposing counterpart. Ventilation elements located above the openings allow a constant air flow independent from the windows and doors. This applies to both external and internal openings. The protruding porch remains a central element throughout the transformation of the vernacular typology.[5,6] To simplify the roof construction, a recess on the south facade replaces the protrusion, creating a covered space that marks the entrance. Unchanged in function, the porch serves as a threshold between inside and outside and leads to an anteroom.

The anteroom is living room, micro-kitchen and hallway in one, with all other rooms connected through it. The bathroom is positioned away from the communal area and is fitted with a toilet and a shower. Under the window there is space for an optional hand basin. A full-size basin is placed outside the bathroom in the micro kitchen. Following the traditional layout, a central wall divides the space into a public front and a private rear. The private sphere is further divided into 2 mirror-symmetrical individual rooms.

Structurally, the building is a solid construction with a tectonic roof. To minimize thermal mass, the outer walls have the standard thickness of around 10-12cm or one brick width (W1). The slender shell is held together by the inner walls (W2), which are laid in block bond, replacing the usual concrete ring beam. Another attempt of structural reinforcement through segmentation is the folding of the masonry in the south facade.

The shell's final deviation from common practices is its roof construction. What appears to be a hipped roof with a pitch of 40° or 80° from the outside is more accurately described as a pseudo-hipped roof. The primary structure is based on regular trusses, while the steep hips are formed by an overhang of the battens that decreases towards the ridge. The pseudo-hipped roof combines the structural simplicity of a gable roof with the significant advantage of a shaded and weather-protected gable wall. Furthermore, the gap between the gable wall and the pseudo-hip allows for cross-ventilation along the longitudinal axis of the roof space.

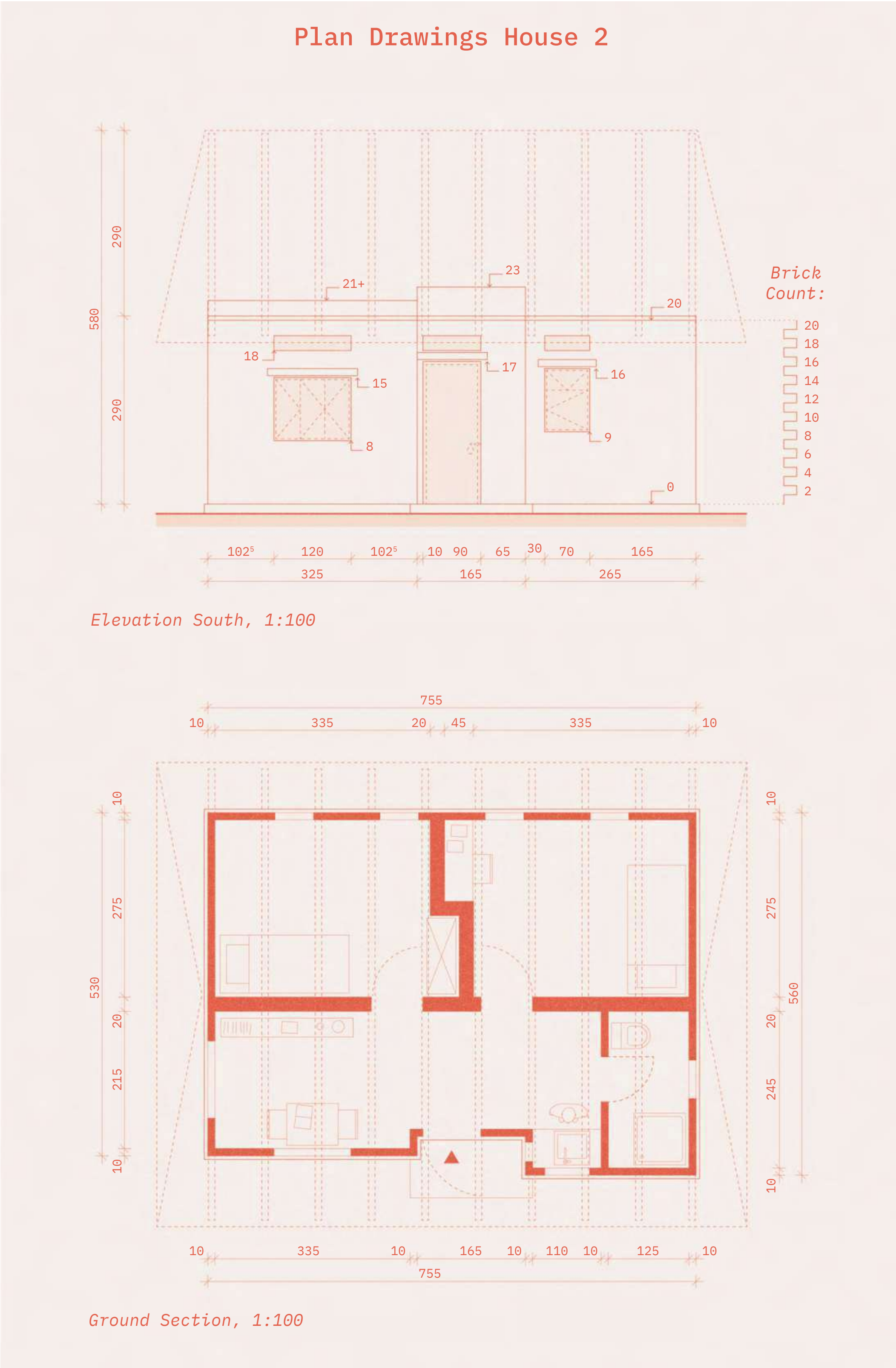
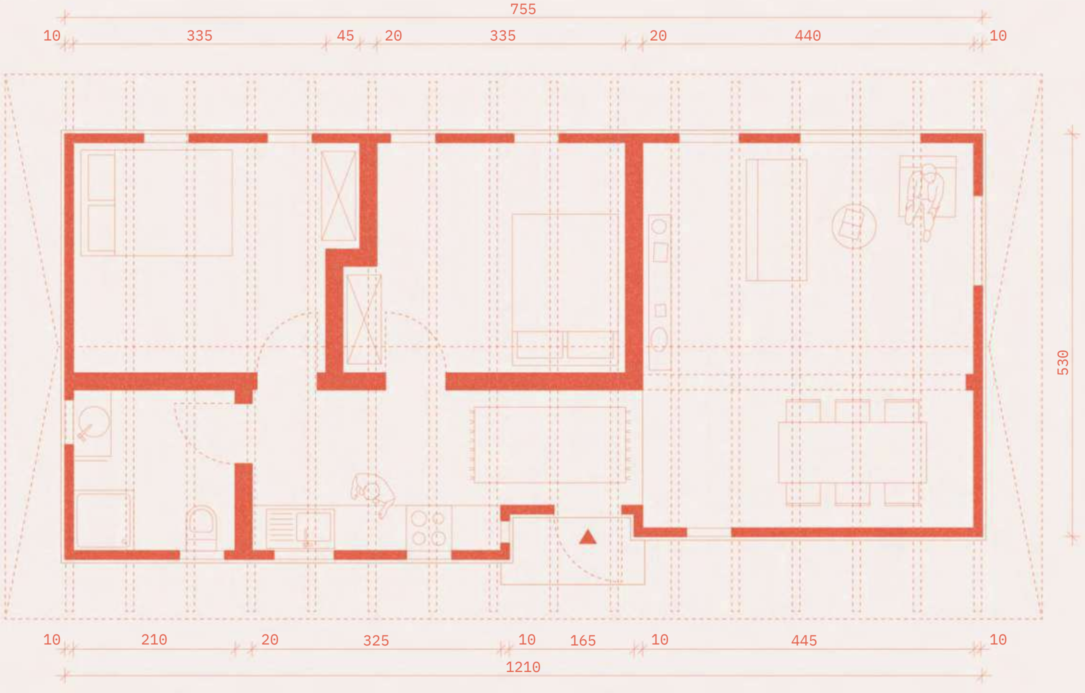


fig.11 Plan drawings: House 2; 1:100. The original construction drawings showed a few more dimensions.

Plan Drawings House 1

fig.12 Plan drawings: House , 1:100.

Elevation South, 1:100



Ground Section, 1:100

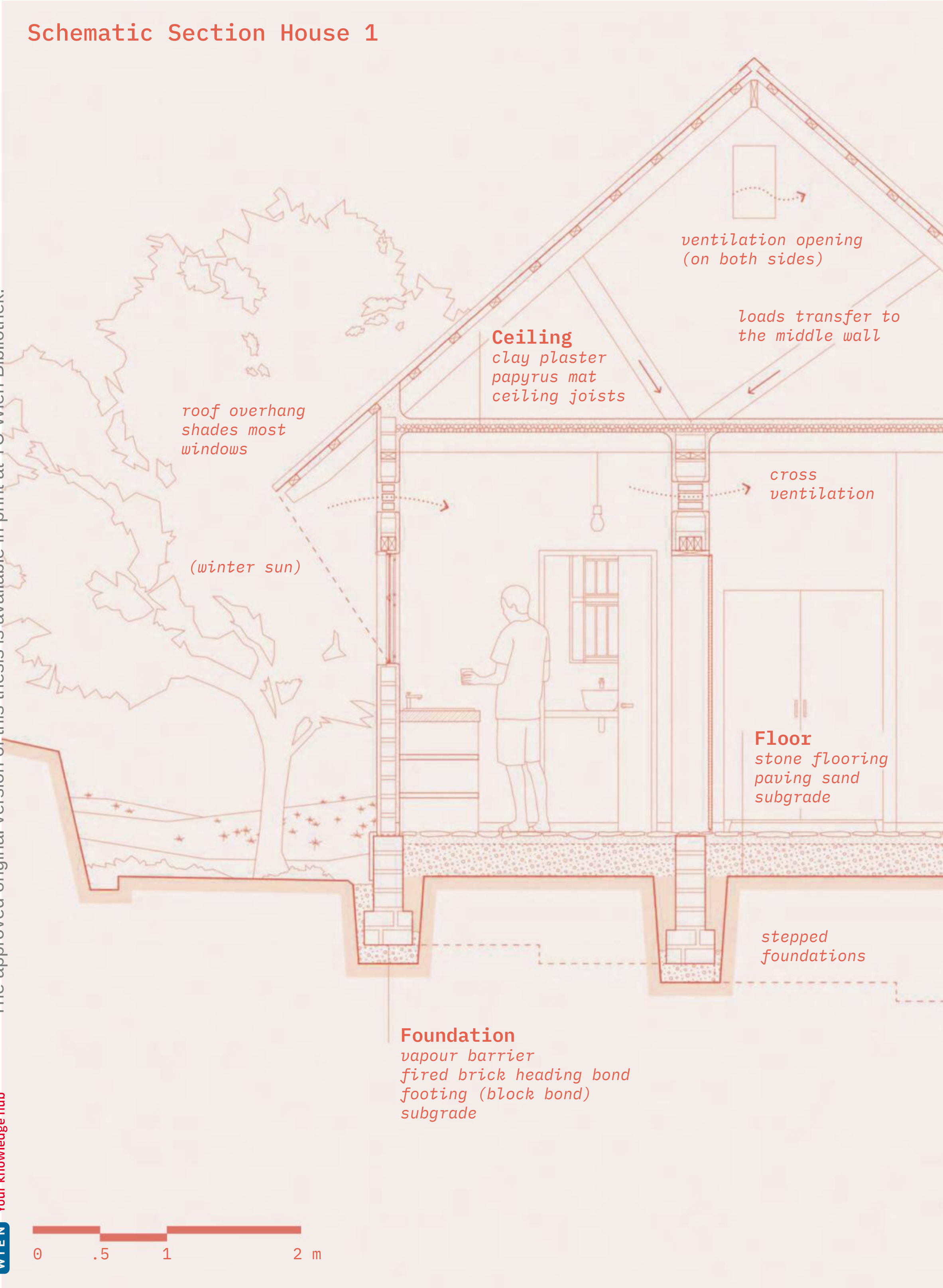


fig.13 Section House 1 as built, 1:45. From left to right: kitchen, bathroom (at the back), individual room.

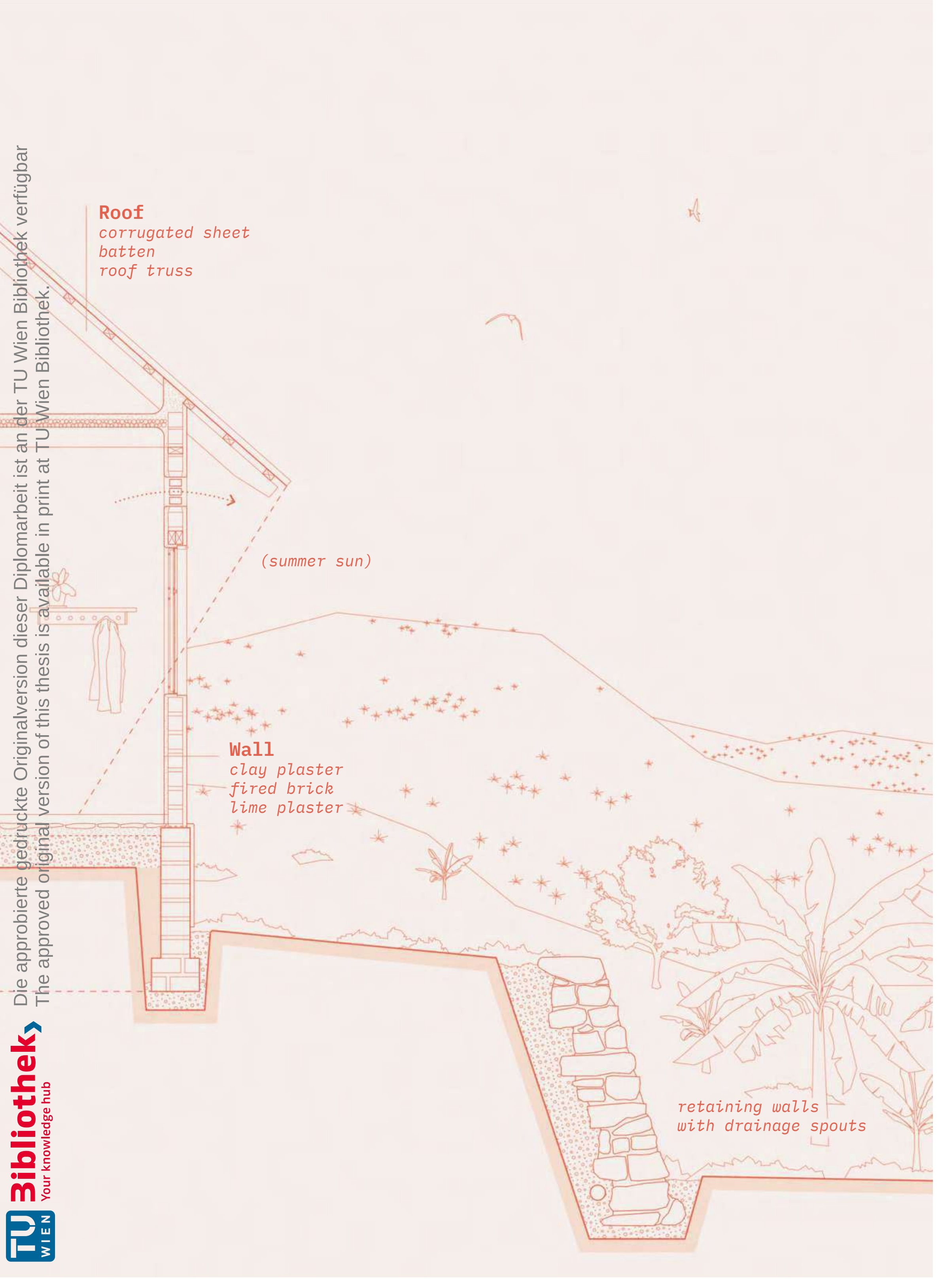

Roof
corrugated sheet
batten
roof truss
(summer sun)
Wall
clay plaster
fired brick
lime plaster
retaining walls
with drainage spouts

fig.14 Site plan as built; no scale. The plan juxtaposes the built layout with the intended layout as described in this chapter.

As Built ≠ As Planned

Instead of formulating additional building details and components, we compiled a list of material experiments that we wanted to carry out during the Building Workshop. The results of the tests were to determine the further design of the buildings. The section drawing on the previous page provides a preview of the final form, construction, and materialisation of the completed buildings. The underling experiments are presented in the next chapter.

Lisa and David traveled to Uganda in late 2021 to initiate preparatory works together with Paul. On site, they took two decisions that deviated significantly from the presented plans. The building site was moved away from the property boundary and into steeper terrain in favor of additional arable land. The trade-off is increased excavation and earth movement, as well as noticeably higher and longer retaining walls. Also, the access road has become slightly longer and the optional extension of the road to the northern property boundary will be more complicated. The second decision concerns the location and orientation of the buildings. The order of the two residential buildings was reversed and the alignment changed. The floor plan of House 2 was mirrored. To further increase the privacy of the larger House 1, the floor plan was left unchanged, so that the living room now faces away from the square. As the diversions have no influence on our research questions, we consider any further comparison to be irrelevant to the work.

1 Mass, B. (2024) *For Example Bowa Hill - On the Transformation of Contemporary Vernacular Architecture: Thermal Comfort and Environment*, p. 22. Vienna: Vienna University of Technology.

2 Ibid., p. 105.

3 Ibid., pp. 102.

4 Ibid., p. 112.

5 Weidacher, M. (2024) *For Example Bowa Hill - On the Transformation of Contemporary Vernacular Architecture: Building Culture and Materials*, p. 175. Vienna: Vienna University of Technology.

6 Ibid., pp. 83.

C

Construction

Construction Diary
Learning from Bowa Hill

The construction diary is divided into 3 parts and documents a period of one year. Each part corresponds to a phase of construction. The first part summarises the preparatory work from November 2021 to January 2022. The second part documents our field trip to Uganda and the subsequent Building Workshop on Bowa Hill. The third and final part of the construction diary shows the completion of the first phase of construction after we had left.
Initially the working title „Learning from Bowa Hill“ was a note to ourselves. A note, not to forget, that the construction process as well as the completed buildings are primarily a testing ground for the project. In addition to the relation of implementation to research, defining our role within the process appears equally important to us. Through what is best described as participatory observation, we saw an opportunity to complement our research with empirical findings and to evaluate previous hypotheses. In contrast to the previous chapters the construction diary is based on a methodology that relies on subjective observation.

Preparatory Work

November 2021 - Access and Infrastructure

It is the last month of the rainy season when David and Lisa arrive in Uganda. In the coming weeks before our arrival they will make initial preparations and try to find companies and people to carry out the planned work. But already the supposedly simple first task of finding suitable accommodation for the duration of the construction site turns out to be more difficult than expected. Actually, the difficulty is not in finding something suitable, but rather in finding accommodation at all, as there are no hotels or homestays in the area around Bowa Hill. The first major tasks, preparing a passable road to the site and the earthworks themselves, are out of the question for the time being. For Lisa and David it is a first test of patience, for us it is a good attunement from a safe distance. We are in touch almost every day.

All of a sudden a lot happens at once. Paul finds a company to build a road and do the earthworks, and a local construction team to dig a well. While the work on the well takes weeks, the earthworks are completed in just two days. Shortly after, the cistern is delivered and it seems that we are finally on track.

December 2021 - Layout and Retaining Walls

But the next challenge was not long to come: finding a local builder to work on the retaining walls. Paul's calmness, his linguistic and cultural mediation skills and his (initially sparse) contacts in the region are indispensable. We come to terms with the fact that we are not always privy to all the details of agreements – eventually, this is also part of the observation process.

At Bowa Hill, Lisa and David install string lines to mark the position of the 3 buildings and the corresponding retaining walls. After countless negotiations, Paul finds a contractor willing to work with quarry stone from the site. Once again, the tough negotiations contrast with the unexpected progress of the work that follows. Sometimes even too fast for our liking! The irregular shapes of the quarry stones are accommodated by a generous use of mortar; the intended drainage layer between the retaining wall and the ground is rarely created. Paul says that the extra effort of a drainage layer is not common in Uganda.

The images of the first completed retaining wall are a surprise to us. While we are pleased with the progress of the construction, we didn't expect the site to be moved this far into steep terrain.

January 2022 - Robert

When a dispute arises with the contractor hired to build the retaining walls, Paul starts looking for another contractor to build the first buildings. This time he extends his search to the GKMA. Paul argues that not only are there more contractors here, but they are also more skilled and reliable than those in the countryside. Through his many contacts in the capital, Paul is put in touch with a builder called Robert. Lisa, David and Paul meet Robert at one of his ongoing construction sites. He shows them his work and they discuss the planned project. After further negotiations, Robert is commissioned to carry out the shell work on the 3 buildings.

It is mid-January when Robert arrives at Bowa Hill with 9 workers. They plan to live in a tent on the site for the duration of the construction, which Robert says will probably be 5-6 weeks, working 7 days a week. We get pictures from the site every day and support the work as best we can from afar. By the time we leave Vienna, the workers have competed the foundations and started to build the walls of the workshop building and House 2.

Building Workshop

Day 1 - Hotel Networth

It is already light outside when we wake up under our mosquito nets. Images of yesterday's drive from Entebbe to our hotel in Wobulenzi flash through my mind: thick clouds of smoke from a scove kiln on the edge of a swamp; the shacks of an informal settlement next to ostentatious houses; street vendors in Kampala's traffic chaos; the blue neon lights of street food vendors enveloped by the warm darkness of the night.

We had decided not to set an alarm clock to recover from the long and exhausting journey. We will take the first day slowly, staying within the grounds of our hotel, oddly named 'Networth'. The complex itself is large and labyrinthine, an interweaving series of different one-storey buildings. Everything here is architecture without architects. And although we had decided not to work today, we quickly realise that our accommodation is an ideal place to observe various aspects of the local building culture: construction details, materials used, formal qualities, deterioration and damage.

Hotel Networth appears to us as a small universe of what we have summarised under the term common practice. In this universe we will live for the next 3 weeks.

Day 2 - Head Over Heels

First thing in the morning, we drive to the construction site. By car it takes about 30 minutes from Wobulenzi to Bowa Hill. When we arrive, all 3 buildings are being worked on. Everything looks strangely familiar. The walls of the workshop/garage building and House 2 are almost finished, only a few rows of bricks are missing to reach the lintels. Most of the workers are digging the trenches for the foundation of House 1. The site appears chaotic but we soon realise that there is an order to things that we do not yet understand. Instead of a rigid organisation, everything is subject to a flexible flow.

Naturally, our arrival does not go unnoticed. It seems as if the workers can't figure out who we, the strangers, are and what we are here for. If they were to ask, the most honest answer would be: "Among other things, to find out". Just as Paul described Robert the builder to us, he is modest and friendly. When we ask what we can do and offer to help, everyone seems irritated. Once we get down to work, however, the initial irritation disappears quickly and after a short time it feels as if we have been part of the group for a long time. At least to us. While the workers continue to dig the trench for House 2, we help to collect stones on the site. As soon as the trench reaches stable ground the workers stop digging and we bring in the subgrade. First the collected stones, then gravel. Stones that are too large are broken into smaller pieces with a sledgehammer. For protection the workers squint or turn their heads. Occasionally they close their eyes. What we bought as local gravel was manufactured in the same manner.

As we begin to lay the foundations, Robert explains that the brick bond we intend to use for the base is unusual in Uganda. With a lot of tweaking we find a solution, but soon understand why the bond is not common: as the format of the bricks does not take into account the joint dimensions, it is generally difficult to lay a uniform bond. The more complex the bond, the more adjustment is required. Contrary to what we assumed in our research, the noticeable large mortar joints are therefore only partly due to the irregular geometry of the handmade bricks.

By the end of the day we are finished with the base of the foundation. It's just after 6pm, soon it will be dark.

Day 3 - All Foundations Complete

Now that the whole team is working on House 1, the different roles are clearer to us. Abdul, Thomas, Kamoga and Shalif are masons; Barak, Ras, Jamil, Shalif and Lawrence are porters. The porters are the youngest on the construction site. While the masons work exclusively on the building itself, the porters, as the name suggests, are mainly involved in preparing and fetching building materials.

We observe that the work flow stands or falls with the work of the porters, whereby the mixing of cement mortar is of particular importance. There are two aspects to the job: firstly, porters must ensure that there is always enough mortar mixed (but never too much) and that each mason has enough mortar to work with; and secondly, and just as important, the porters are also responsible for the quality of the mortar itself. Apart from the quality of the mortar, the porters are also responsible for the quality of the food. Each day, one of the five takes on the additional task of cooking breakfast, lunch and dinner. Despite the clear hierarchy within the construction team, the atmosphere is friendly and cheerful. Work on the foundations is progressing quickly and without complications. By the end of the day, the foundation of House 1 is complete and parts of the drainage are already filled in!

Day 4 - Days of Bricklaying

The next few days are all about bricklaying. Robert asks us to mark the position of the openings. Now that we are here, he seems happy that we are taking on this task. Although he can read the plans, he is not used to working with them, he says.

Between the foundation or base and the brickwork, we put a thick foil as a horizontal moisture barrier. The masons first construct the four corners of the building. They lay 7 rows of bricks, plumb and square, and then join them in a second step. The process seems very efficient. Less efficient, however, is the collection and crushing of the rocks for drainage, and soon it becomes clear that the workers are not particularly happy about this task. It is only when we fill in the remaining gravel and finally some of the excavated material that their spirits are lifted. Amused, Robert explains that drainage is not something that is normally done in Uganda.

Day 5 - Wood or Concrete?

It's still quiet at the boda stand in Wobulenzi. The sun has just risen. Ben and I have decided to get up early today and take the boda (motorcycle taxi) to Bowa Hill. We increasingly feel that the car is separating us from our surroundings. The daily journey is both tiring and boring.

We talk to two drivers and agree on a price. 30 minutes and a long, interesting conversation later, we arrive in Kimwanyi. The journey has gone by in an instant. After a quick breakfast at the general store, we set off on the 15 minute walk to Bowa Hill. Birds are chirping, leaves are rustling in the wind, the smell of smoke is in the air. What a morning!

At the construction site, it is another day of bricklaying. The walls of House 1 are growing fast, but they don't look particularly strong. The fragile, unstable masonry puts the commonly used ring beam in a new light. Sticking to our original plan to reduce the use of steel and cement by making all the lintels out of wood seems irresponsible to us. We discuss the situation with Robert and agree to connect critical sections of wall with continuous beams of reinforced concrete. The remaining lintels will be fashioned from timber as planned.

Day 6 and 7 - Working on the Scaffold

Since yesterday afternoon we are working on a scaffolding. Unlike what we are used to, the local scaffolding moves with the work. First around and then into the building. The slender walls tremble as the holes for the horizontal supports are chiseled.

After four days of continuous bricklaying, we notice something else. While the masons are accurately grouting the side of the wall facing them, they are leaving the opposite side untouched. This practice results in an asymmetry in the joint, which in turn contributes to the instability of the brick bond. Again, the custom follows very pragmatic considerations: since the inside will be plastered anyway, it is sufficient to plane the outside for the time being. Given the thinness of the walls, even the plaster is likely to be statically relevant. Certainly, the steel frames for windows and doors will add to the structural integrity of the system.

Soon the roofers will join the construction team and we consider starting with the roof of the workshop/ garage building. Using a small model, we show Robert the construction method we have in mind. He is skeptical once again, but not dismissive; together we draw up an order list for the timber merchant. Tomorrow we will be building walls all day again.

Day 8 - Concrete Works

Patrick and Moses, the two boda drivers, are already waiting for us when we arrive at the hotel car park in the morning. If we didn't know better, we wouldn't believe that today already marks the beginning of our second week in Uganda.

Arriving at the site, we soon receive the wood we ordered yesterday. On time, we have all the materials we need for the upcoming work. While most of the workers are still busy with the brickwork on House 1, a small group is starting to prepare the form work and reinforcement bars for the concrete beams.

Like the mortar, the concrete is mixed on the ground. A cavity has formed in the mixing area from which the water is slowly seeping out. Robert has bought gravel – probably granite – from the nearby quarry as an aggregate for the concrete. The stone is much harder than the local gravel we have been using so far.

We finish the concrete work on House 1 in the late afternoon, ending the working day earlier than usual. Dark clouds are gathering in the distance to the northeast.

<u>Day 9 - A Full Day</u>

On the way to Kimwanyi, we stop in Nakaseke to buy breakfast for the team. As we eat together, the workers tell us that it rained heavily last night. They have protected the fresh concrete with planks and empty cement bags, so everything is fine.

In contrast to the rather monotonous last few days, there is a lot to do today. The masons start preparing the form work for the concrete work on House 2. The porters peel the eucalyptus logs from which we will make the roof trusses for the workshop/garage building. Ben and I work on the wooden lintels. The timber (5cm x 10cm) is badly warped and, to put it mildly, very damp. To get the necessary cross section, we nail 2 beams together. By matching them in pairs, we manage to assemble reasonably straight beams. The lintels are fitted relatively quickly as the cross-section is roughly the same as that of the bricks. Once the lintels are in place, it's back to bricklaying.

Robert's roofers arrive at Bowa Hill around midday. Compared to the bricklayers, Mathias, Suleyman and Julius are surprisingly young. They speak little English, so Robert translates for us. After a brief conversation, they get straight to work. Like the bricklayers, the roofers only need a few tools: a bow saw, a tape measure, a string line and three claw hammers. From empty cement bags they cut nail pouches.

Despite the many tasks, work is going well today. When we leave Bowa Hill in the evening the first truss of the workshop/ garage building is finished and the masons are pouring the remaining concrete lintels.

Day 10 - Two Disagreements

Robert left this morning and won't be back for a few days. Lawrence, one of the young porters, will take over communication if necessary as he speaks English best.

The roofers finished all the trusses yesterday and have already erected and installed them. When we arrive they are busy fitting the battens. While the trusses are made from thin logs, the battens are made from sawn timber. With Lawrence's help and the structural model, we explain the construction of our pseudo hipped roof. It takes a lot of persuading to get the roofers to remove some of the battens that have already been fastened and install them in a way that they are not used to. When the first cross batten is in place, everyone is visibly relieved.

When we realise that the bricklayers have not installed any ventilation above the internal doors, we dread the discussion that lies ahead. So we ask Lawrence how to handle the situation. Contrary to our expectation, the workers are not so much annoyed by the dismantling as they are puzzled and amused. With regard to privacy, they explain to us, that it is not customary in Uganda to install air vents indoors - especially in the bathroom.

Day 11 - Our First Farewell

Today is our first farewell. The masons finished all the work on House 1 yesterday and plan to complete House 2 today. While they are busy with the last layers of bricks, the roofers are starting to lay the corrugated metal roofing.

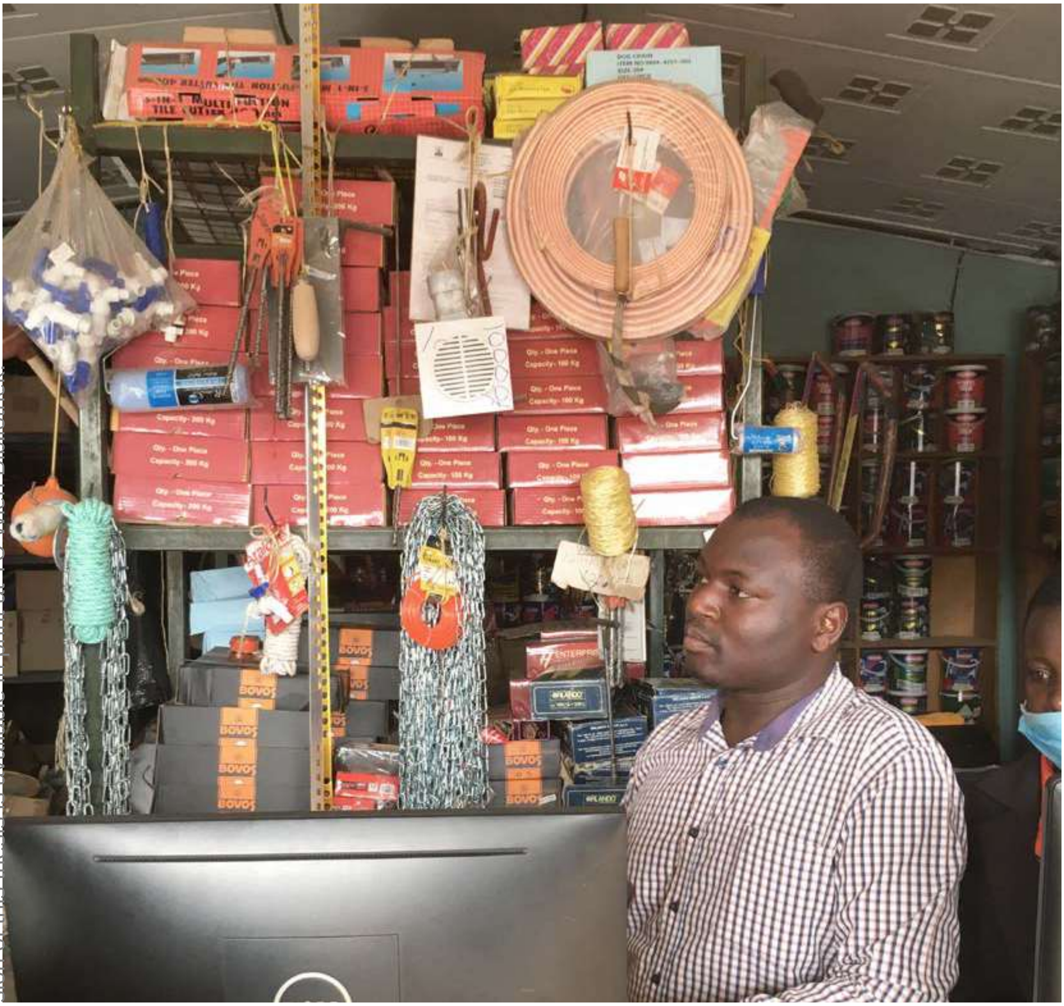
In the early afternoon, the masons finish their work on House 2. They quickly wash up, pack their bags and change. Meanwhile, Robert returns to the site and pays the workers their wages. After almost a month on Bowa Hill, they are clearly all looking forward to going home. And the large wads of cash are no less of a reason to be in good mood. It is a warm farewell and we quickly exchange phone numbers. As soon as the masons and the porters have disappeared over the top of the hill, an unfamiliar calm settles over Bowa Hill.

Tomorrow we want to start our first experiments. A conversation with Robert reveals that he is not interested in doing the interior work if it involves earthen materials. However, seeing the interest Lawrence has shown in the last few days, Robert supports him staying on at Bowa Hill to help us with our experiments, and even longer if necessary - much to our advantage, as we will soon find out.

Day 12 - Muli, Emuli

On our daily boda ride in the morning, I ask Patrick if he happens to know if it's easy to buy emuli, the local reed. He is surprised at our very specific interest, but says that the plant grows in abundance in the region and that it is generally very easy and cheap to buy. Arriving in Kimwanyi, Patrick takes the initiative and speaks to the first person we meet. The woman asks us to write down the phone number of a man called Moses. A few hours later we meet her and Moses (who turns out to be her husband) on Bowa Hill and discuss the arrangements.

At Bowa Hill the roofers are ready to start framing the roof of House 1. First they fix the bottoms (local term for wall plate) to the masonry with pions (steel straps). Once again, the walls shake as holes for the fasteners are chiseled. Next, the eucalyptus logs from which the roof will be made are sorted. Strong and straight ones for the rafters, bottom chords and joists; crooked, thin ones and offcuts for the bracing. Our suggestion that it would be structurally better to make the bracing asymmetrical according to the position of the center wall is met with resistance. As before, it takes a lot of convincing (and Lawrence's help) to do something that is not common practice.



Day 13 - Tofa's Hardware Store (and Others)

The largest and best-stocked store for tools and building materials in Wobulenzi is Tofa's Hardware Store. The shopkeepers already know us from previous purchases. We buy bricklayer's and smoothing trowels, various types of metal mesh, all kinds of nails, machetes for tomorrow's emuli harvest, new measuring tapes, a bag of cement and a bag of hydraulic lime. In a shop that sells seeds and pesticides, we find a good quality pressure sprayer for our experiments with the plaster.

Halfway to Bowa Hill, Lawrence calls us. The roofers need more 1" and 2" nails, 5 kg each, as well as 5 kg of roofing nails and rubber washers. In Nakaseke there is another, smaller dealer in tools and building materials. You can get almost anything there, too, and what they don't have in stock can be ordered within a day, often less. Prices here are slightly higher than in Wobulenzi, but the Nakaseke shop is the closest to Bowa Hill.

Also, we can place our orders by phone and they bring them to the site by motorcycle taxi. Transport is often the most expensive part, both for the supplier and the customer.

After our discussion yesterday, things are running smoothly again on site. We notice that the roofer rarely uses a tape measure. The first beam is constructed directly on the wall plates, with each subsequent beam placed on top of the previous one. Piled into a high stack, the beams only need to be moved the shortest distance possible.

While the roofers are busy installing the trusses, the diagonal bracing and the battens, we start preparations for our experiments. We build 2 screens, 2 trestles, a worktop and a short ladder from scrap wood. We nail a 1 cm mesh to one of the frames and a 3 mm mesh to the other. The slope from the earthworks for the two houses seems the ideal starting point for our experiments with earthen building materials. Together with Lawrence, we dig out the material, sift it through our sieves, water it in wheelbarrows and cover it up overnight.

By the time we head back to our accommodation in Wobulenzi in the evening, the framing work on House 1 is complete. Tomorrow the roofers will start laying the metal sheets.

Day 14 - Emuli Harvest

We meet Rachel early in the morning at the general store in Kimwanyi. As agreed, she takes us to one of her plots of land, or gardens as they are called in Uganda, to help her with the emuli harvest.

After almost half an hour's drive we park the car at the side of the road. Rachel leads the way. Her path takes us along small fields and through dense vegetation. The path gets narrower and narrower with every turn. As we descend, the vegetation thickens. Arriving to a small rippling stream, they rise in hundreds, slender and several meters high: emuli.

Without hesitation Rachel and Lawrence begin the harvest. We watch as stalk after stalk falls under the well-aimed blows of their machetes. The soft and green tip of the plant as well as the long, sword-shaped leaves are removed in a second step. As most of the leaves are already dry, a light twirl is usually enough to separate them from the stem. With five of us, the harvest progresses quickly. Soon we find ourselves in a sea of emuli residue.

While David, Ben and I are still discussing the best way to carry the stalks to the car, Lawrence has already started preparing bundles. To tie the bundles, each of which holds about 30 stems, he uses half-dried fibres from the trunk of a banana tree. His movements are skillful and with a certain routine. Noticing our fascinated gazes, he laughs out loud. And although he can't quite see why we're always most enthusiastic about such trivial details, he still seems proud of all the things he's shown us today.

Day 15 - Framing and a Floor

Yesterday evening the roofers finished their work on House 1 and slept inside for the first time. When we arrive at Bowa Hill in the morning, they are already busy installing the wall plates on House 2. As this is the third roof, we are not worried about anything going wrong.

Today we want to start working on a floor made of stone. As a location for our first experiment we have chosen the workshop/garage building. Having created a small sample beforehand, we are confident that our experiment will work on a larger scale. So actually, the first experiment is not really an experiment but rather a large sample. What follows is a brief description of the process.

The ground work begins with digging a trench that is deep enough and as even and flat as possible. It is a tedious process as we keep running into large rocks, sometimes too big to be removed. For the subgrade we use the same gravel we used earlier for the drainage. We level and compact everything, then move on to the next step. As our search for a geotextile had been unsuccessful, we bought large bags of woven plastic, usually used to store cereals or flour. We cut the bags open and form overlapping fields. Next we bring in coarse sand and level it flush with the top of the foundation. At the edges, we place the flat stones we have collected on site in a bed of clay mortar. For the mortar, we sieve the excavated material through a 3 mm sieve and mix it with coarse sand in a 1:1 ratio (the mortar is easy to work with and seems to hold up well once it has dried). We lay the edges first and then continue to work on the in-between using a stringline - similar to the way bricklayers used to lay bricks. The stones are easy to level in the sand. Originally, we intended to use lime mortar for the grout. However, as the lime hydrate turns out not to be very reactive, as we had feared at the time of purchase, we see no other option but to add cement to the mix. The mix we use is 4 parts sand and 1 part lime-cement. After the clay mortar has sufficiently hardened, we grout the stones and clean the surface with a damp sponge. In addition to the stone floor, we made two more floor samples. While attempts to produce a pure lime-bonded screed were rather unsuccessful, experiments with compacted earth were much more promising. However, given the specific knowledge required to make a rammed earth floor, the unresolved termite problem and the lack of time, we decided not to pursue further experiments.

Day 16 - Plaster Experiments

There is little work left to be done on House 2. With a sense of relief, the roofers say they will finish their work tomorrow and leave for Kampala next day. We, on the other hand, wouldn't mind staying a little longer. In the 5 days we have left, we want to devote ourselves entirely to our experiments. As our testing ground, we choose a room in House 1. Here we can work in the shade and are protected from any rain showers. We start with a series of experiments on interior plasters. Using a matrix, we prepare a total of 18 different samples, each measuring about 30 cm^2. The binders we use are sieved excavated soil from the site and the much finer and stickier swamp clay; as aggregates we use coarse and fine sand and dried, shredded banana fibers. Due to the unevenness of the walls, the thickness of the plaster varies from 2-5 cm. If more plaster is required to create an even surface, we apply it in 2 coats. With regard to processing, we can already rule out both the swamp clay and the banana fiber test series. The swamp clay appears to be too sticky and the available fiber too stiff to work with. As for the rest of our test matrix, we will only be able to evaluate and compare the remaining mixes with soil from the site in a few days' time.

Day 17 - Lawrence's Knowledge

Today we plan to look at two components: the knee wall and the gable wall. After the first successful results with the clay mortar, we are convinced that we can get by without cement for the knee wall. We build a short section of wall with burnt bricks and mud mortar, and again time will tell if we are right with our assumption. To simulate the structure of a truss, we build a lattice from scrap eucalyptus logs. First we want to try to make a substructure from mats of pounded emuli poles. As with any wattle and daub, the substructure is then plastered in a second step. The pounding itself goes well, but due to the small diameter of the stakes, the mats are quite narrow. As we begin to weave, Lawrence interrupts us, irritated. We're doing it wrong, he says. When we are done with our "experiment" he will show us how to do it properly.

After the first few moves we understand that no further experiments will be necessary. Lawrence ties opposing pairs of emuli to the vertical poles. Together we mix the unsifted soil from our excavation with water to form a relatively dry, yet mouldable, mass, which we then tamp into the horizontal emuli farmework. At our insistence, we make a second sample using a mixture of 1 part excavated soil to 1 part coarse sand.

Day 18 - Repair Works and a Surprise

Robert arrives at Bowa Hill early in the morning, thick wads of cash in his backpack once again, this time for the roofers. The three of them have already packed and are eagerly awaiting to receive their wages and return to Kampala.

Together with Robert, Samir, the young mason, has returned to the site. We discuss what needs to be done to complete the shell of the building. Most important is a structural repair at House 2. The corner post in the entrance area, which is already quite slender, has been considerably weakened during the work on the roof. We see no other option than to close the opening. Similarly, many of the air vents, in both House 1 and House 2, have broken under the roofers' hammer blows and need to be replaced. Samir says that he will manage to complete the repairs by this evening. When we present our scaffolding trestles to Samir, he politely rejects the offer. He would rather have scrap wood from the

roof construction, a saw, a hammer and some nails. In no time he nails together two ladders that taper towards the top. Diagonal braces, which extend from the centre of the ladder, support a horizontal bracket at the top. Two more thick, long boards and the mobile scaffold is complete.
While Lawrence and Samir are busy with the repairs, Lisa and David continue to work on the stone floor of the workshop/garage building. Ben and I inspect the tests from the past days. The undercoat plaster mixed with coarse sand (1:1), the wattle and daub mix and the clay mortar seem to hold up well. The cracks that have appeared are within reason. In the afternoon we plaster an area of about 1 square meter to find out how the 1:1 undercoat will behave over a larger area. Earlier than usual, we pack up and head home to Hotel Networth. Or rather, direction home.
For a few days now we have been watching the construction of a small round wattle and daub hut on our way to work. This morning we saw that the hut has been covered with grass. The first grass roof! As we pass by on our way back, we park the car at the side of the road. A group of men are sitting in front of the main house. As we approach, the youngest welcomes us. His name is David. He asks kindly why we have stopped and if everything is all right. "Well, because... because of the grass roof, actually." General laughter. What's so special about a simple grass roof? We tell them about our building site on Bowa Hill and our interest in how things are done here in Uganda and ask them if they would be willing to show us how to thatch a roof. For a fee, of course, as a workshop at Bowa Hill, including transport and lunch. When? Preferably tomorrow!

Day 19 - Improvised Thatching Workshop

David is already waiting for us outside his house. His uncles should be here soon, he says. An hour later, the two workshop tutors arrive on a motorbike overloaded with long bundles of grass. It rained heavily again last night and the road is in bad shape, they complain.

Arriving at Bowa Hill, we show our guests around the site. It turns out that David is a mason himself. He seems interested in our experiments. We tell him that we want to build the gable walls in wattle and daub, use clay mortar for the knee walls, thatch the open roof areas and so on. And we are still looking for someone to do the job.

As a test area for today's workshop, we suggest the roof of our temporary wood and emuli shed. Said and done. First of all, we need to build a substructure, David translates. To do so, we need emuli, cord and a machete. In a tedious process, we tie a two-layer grid to the wooden slats of the roof structure. The intersections are tied with a knot in which the string is passed on and on, as if it was being woven. It is the same type of knot that Lawrence had shown us during our wattle and daub experiments. Traditionally, banana fibre was used for tying, they tell us, but now it's usually cord from the store. Chord is better but also more expencive. Impatiently we await the next step - thatching. Onto the lattice, the Subi, as spear grass is called in Luganda, is laid in overlapping layers, starting from the eaves. Finally, the loose, thick layer of grass is held down with a few battens. That's it? Admittedly, we thought thatching would be more exciting. Couldn't the Subi be attached in bundles, we ask. Yes, you could, but it's not necessary, our tutors put us off. If we are interested, they can get more Subi and show it to us another day. Yes, but when - the day after tomorrow is our last day on site! Ok then, they say, so the day after tomorrow.

Day 20 - More Plaster Experiments

Much like the surface of the few earthen structures we have seen in the region, all of our plaster samples so far are characterised by significant cracking. Comparing our samples, a 1:1 base plaster mix (1 part screened excavated material to 1 part coarse sand) appears to be the most viable compromise between cracking and abrasion resistance. Fibrous aggregates such as chopped straw, cow dung, or others would be ideal. For the time being, however, we have to work with what we have. We apply a total of 8 different fine plaster mixes to the thoroughly dried base plaster samples. The materials for the samples are fine sand, local excavated soil, swamp clay, termite mound earth and finely chopped banana fibre; all the raw materials are sieved through a 1 mm screen. Naturally, compared to the previous layer, the samples are much more even and consistent. As with the base plaster, a simple top plaster of 1 part sand and 1 part excavated soil seems to work best in terms of application.

With the next experiment, a series of 8 different exterior plasters, we want to observe not only workability, cracking and abrasion resistance, but also the effects of weathering over a longer period of time. Based on our previous experiments with interior plasters, we continue to use only soil excavated from the site. In addition to 2 pure clay plasters, we are applying 6 different lime-cement stabilised plasters to the north façade of House 1. The next rainy season will bring further results.

Back in Vienna, we initiated a collaboration with students at the University of Natural Resources and Applied Life Sciences (BOKU) to examine the soils we used. The results are presented in the next chapter.

Day 21 - Our Last Day at Bowa Hill

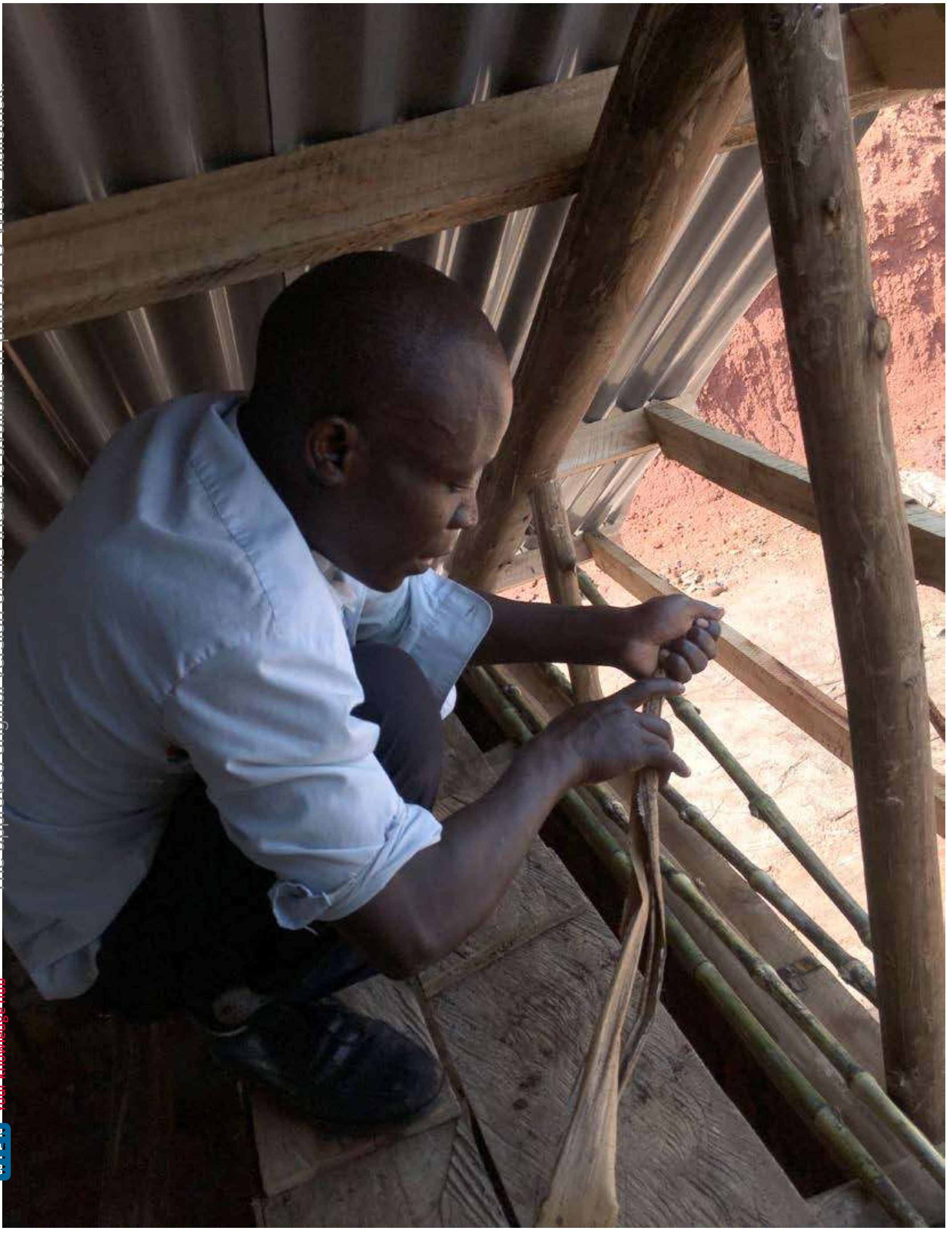
One last alarm clock at 5.30 am, one last boda ride with Patrick and Moses, one last breakfast at the general store in Kimwanyi. If only we had an extra day or maybe two, we think. But isn't it always like that?

Anyhow, the grass roof takes priority today. As our test object for the second part of the thatching workshop, we have chosen the workshop/garage building; once Lisa and David arrive with David and his uncles, we get to work.

As we did two days ago, we first attach a close-meshed substructure from emuli to the roof battens. Both layers of the lattice are made up of pairs; to tie them together we use the same continuous knot that we have already been taught in the workshop. Next we tie bundles of subi - finally! The bundles have an average diameter of 6cm and are tied two hands wide below the root. While tying the bundles, we sort out short and damaged stems and other plants. Starting again at the eaves, we tie bundle after bundle to the emuli lattice, each new row overlapping the previous one. The ends are bent over, creating a loop that prevents the bundle from potentially disintegrating. Lawrence says he has never seen a roof like this before and neither have we. When we tell David about

our pending ceiling experiments, he offers to show us how a ceiling is commonly made in Uganda. We go to House 2 where we prepared an elevated structure that mimics the ceiling construction.
The first step is to divide the ceiling into smaller sections, explains David. Once we have a grid of about 60 x 60 cm, we nail a coarse mesh to the underside. It is similar to chicken wire, but stiffer. We apply a thick, relatively dry layer of plaster from above. When the plaster has set sufficiently, we plaster the underside of the ceiling. Instead of the usual cement plaster, we use our 1:1 clay base plaster. David comments, that it seems to work well, but the drying times are a lot longer than what he is used to. In case our attempts to create a ceiling with better thermal properties fail, this hybrid technology is already a possible alternative.
Other than the conventional ceiling construction, we created 3 more samples. The first ceiling is a clay wrap ceiling made from emuli, excavated clay and subi. As with banana fibre, subi seems to be too stiff to work with. The second ceiling consists of a visible lining of emuli, which acts as a formwork for a thin earthen screed above. Viewed from below, it is very similar to the inside of a traditional Kiganda; the process of making is just as laborious. Third and last, the ceiling with the highest insulation value: papyrus bound into 5cm-thick mats, protected by an earthen plaster on top.
By the light of our telephone torches, we finish the ceiling experiments. Outside, the thatched roof of the workshop/garage building is half finished. Half finished, which fits in well with the rest of the site and is actually what we had hoped to achieve in these 3 weeks.

Living at Bowa Hill

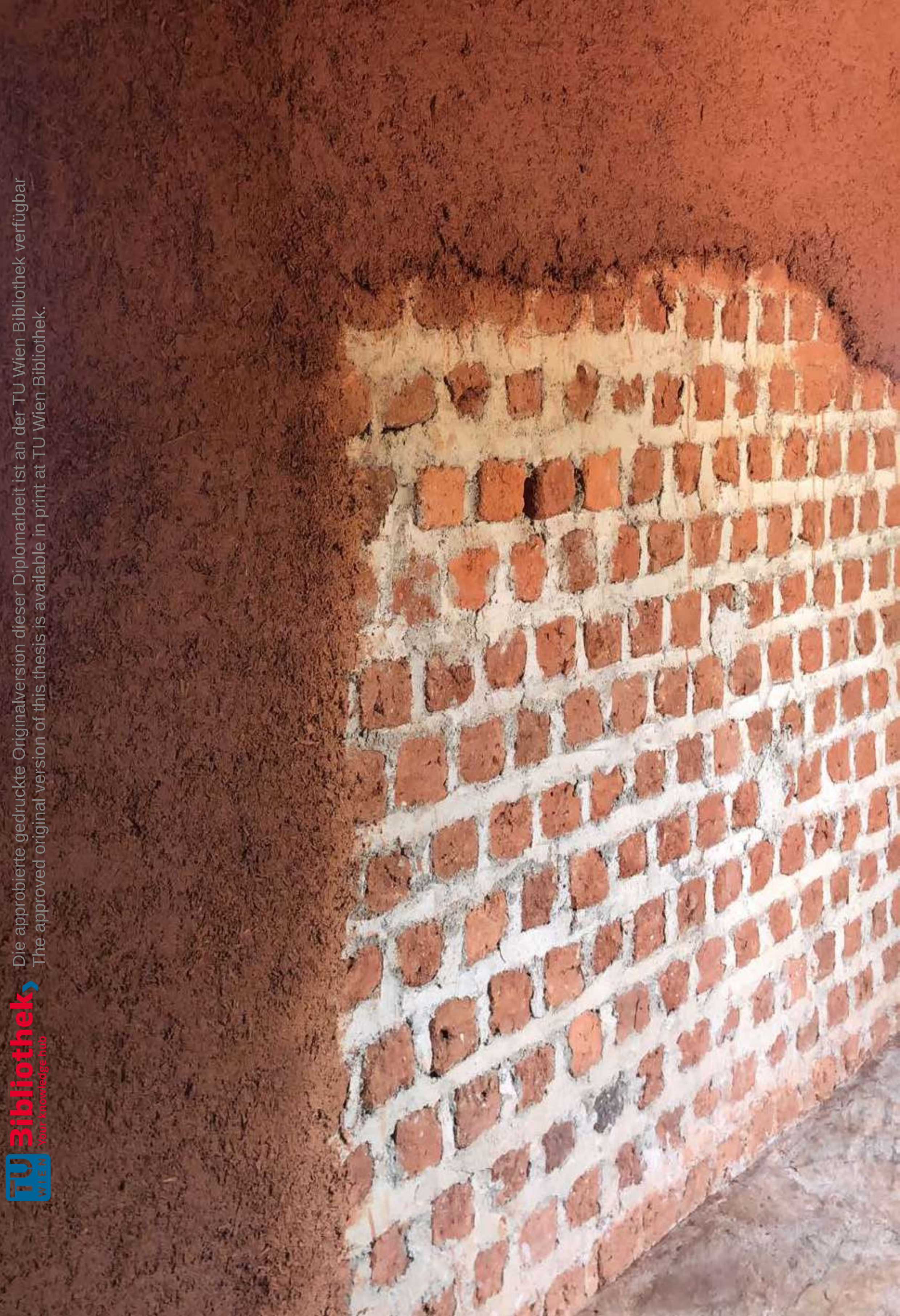


Since March 2022 - Applying and Continuing Experiments

The heavy rains expected for the upcoming rainy season were just one of the many challenges that lay ahead. All of our experiments now had to be translated to building scale, and the list of tasks was long. The biggest uncertainty was whether or not we would find workers willing to work with non-industrialized building materials.

In the weeks (and months) after our departure, Lisa and David were joined by Lawrence, David and David's uncles to complete the works on the buildings. We resumed supervising the site as best we could from afar. Mostly, this supervision involved altering or tweaking mixes, practical advice on application and installation, and general moral support. Our biggest problem, the cracking of the interior plaster, was solved by adding fine fibres to the mix. All the ceilings were made of papyrus, similar to our last attempt; as a temporary solution, the houses have been connected to a septic tank; small solar panels provide basic supply of electricity. Lisa and David have moved into House 1. Two farm workers have moved into House 2; they have built a small outhouse kitchen.

The images on the following pages were taken between March and November 2022 and are presented in chronological order.




Rwenzori


Vim

Thanks to all people involved.

1 Bowa Hill Team: Lisa Marie Alvanos, Paul Senoga, David Vogt. Thank you for initiating the Bowa Hill project and making it happen.
2 Robert's Construction Team: Robert Nsereko; Abdul, Barak, Jamil, Julius, Kamoga, Lawrence Kalanzi, Matthias, Ras, Shalif, Shalif, Suleyman, Thomas. Thank you for your hard work, your patience, the meals and the time we shared.
3 Wobulenzi Boda Team: Patrick and Moses. Thank you for your reliability, the safe rides to Bowa Hill, helping us find emuli and all the conversations we had.
4 Emuli Team: Rachel and Moses. Thank you for the harvest day and supplying us with emuli.
5 Kasangombe Construction Team: David and his family. Thank you for sharing your skills and knowledge with us and for contributing to the completion of the three buildings.
6 Water Team: Kaspar Bomatter. Thank you for the collaboration and your work on site.
7 Support Team: Dominik Abbrederis. Thank you for your free advice at any time.
8 Special thanks to Lawrence Kalanzi for your exceptional involvement. Your support has been invaluable to us.

D

Evaluation

Building Materials Index and Analysis

Benedikt Mass / Maximilian Weidacher

With the evaluation, we turn to the last part of our study. Regarding our first research question on the improvement of thermal comfort, the case study buildings at Bowa Hill are based on findings of preceding assessments. In contrast and due to the circumstances described earlier, when it comes to our second research question and the potential for the reduction of the environmental impact of buildings, our design decisions were rather intuitive. Instead of assessing variables beforehand, we have chosen to evaluate the buildings after the construction. In a series of three evaluations from different perspectives and at different scales, the first chapter serves as an introduction to the following and examines the resources and materials in the immediate project region.

Material and Resource Index

A major part of our research and design was focused on the use of renewable resources and natural building materials in an informal, non-engineered building context. While often romanticized even by scholars from the fields of social anthropology to architectural history alike, our interest in these techniques was not spiked primarily by their cultural and historical value, but rather by their potential to contribute to improved thermal comfort as well as the reduction of the environmental impact of building constructions.

In preparation for further evaluations, we summarised and indexed all materials used for construction and experiments. A map presented at the end of the chapter provides further information about the origin and associated distance to the exemplary building site on Bowa Hill. While most of the indexed materials can be clearly assigned as either industrial materials or renewable resources, there are still some that fall somewhere in between.

Industrial Building Materials

Industrial materials, such as cement or metal products, are resource intensive, highly processed, and notorious for their long production chain, embodied energy, and large ecological footprint. At the same time, they are expensive and not always readily available especially in more remote areas. From a builder and homeowner perspective, these materials require relatively low labor input during construction phase and are considered low maintenance. The research includes the following industrialised building materials:

- i.1 hydrate lime
- i.2 portland cement
- i.3a galvanized steel sheet
- i.3b powder coated steel sheet
- i.4 reinforcement steel
- i.5 steel wire mesh
- i.6a steel nail
- i.6a galvanized steel nail
- i.7 window glazing

Renewable Resources

In contrast to industrial materials, sustainable and renewable resources are widely available, particularly in remote areas. They can generally be sourced for low or even no cost. In tropical climates, emuli (elephant grass) reeds or essubi (speargrass) grow in biannual cycles that correlate with dry and rainy seasons, leading to high yearly yields and a fast growth rate that is unmatched by moderate climate zones. Just like there is an abundance of such fibrous renewable materials, clay-rich soils are a geological characteristic of Uganda's Central Region, as was already shown in the first research chapter.[1]

Compared to industrial materials, the use of renewable materials requires high labour input. In the context of Uganda however, manual labour is among the cheapest and most easily available resources. While prices for industrial

Soil Samples

Sample ID*	Sample Name	Distance to construction	Depth from surface
[205]67	On-site Soil I	0.1 km	0.7 m
["]68	Unfired Clay Brick I	17.7 km	0.5 - 2.0 m
["]69	On-site Soil II (Well)	0.3 km	3.0 m
["]70	Kimwanyi Road	0.5 km	-
["]71	Unfired Clay Brick II	7.4 km	0.7 m
["]72	Swamp Clay	13.0 km	0.7 m
["]73	On-site Soil III	-	0.5 - 2.0 m
["]74	Termite Mound IV	-	-

*Internal cataloguing system, Institute of Applied Geology, BOKU.

fig.1 (left page) Industrial, semi- industrial and renewable building materials.
tab.2 (above) Provenance of soil samples.

materials are not significantly lower than those in Austria or Central Europe, semi-industrialised building materials of the in-between category are both locally available as well as affordable. The research includes the following renewable resources and semi-industrialised materials:

- r.1 clay soil
- r.2 gravel
- r.3 sand
- r.4 flagstone
- r.5 speargrass (essubi)
- r.6 papyrus stalks
- r.7 elephant grass (emuli)
- r.8 water
- r.9 banana fiber
- s.1 fired brick
- s.2 round timber (eucalyptus)
- s.3a sawn timber (muvule)
- s.3b sawn timber (unspecific)

Clay Analysis

Since the majority of alternative components contain clay, the second part of this introduction is devoted to this single material. Before we left for Uganda, we had already been in touch with Prof. Franz Ottner from the University of Natural Resources and Life Sciences (BOKU), to see whether it would be possible to analyse soil samples at the Institute for Applied Geology's laboratory facilities. As part of a constructive project for the Masters' Programme in Civil Engineering and Water Management, two students carried out a mineral analysis of different soil samples we collected during the building workshop. It is important to note, that such analyses are not comprehensive for construction purposes, as they do not include important indicators like Proctor compaction tests for maximum dry density or the Atterberg limits for shrinkage and plasticity. However, they still they help to explain some of the observations made during the material experiments on site.

The results presented in this paragraph are based on the student's final paper,[2] whereas the interpretation can be attributed to the authors of this study. Below, we will focus on spotlighting the most relevant results of the analyses conducted at BOKU, i.e. grain size distributions of the complete samples, as well as the analysis of the clay mineral fractions. Along with the indexed materials, the source of the samples is indicated in the material map.

In total, eight different samples were analysed and compared. Tab. 1 (above) gives an overview of the samples and their origin. Samples are named consecutively after the Institute of Applied Geology's internal cataloging system, starting with number 20567, however we drop the first three digits to improve legibility. Five of the samples (67, 69, 70, 73, 74) were taken directly on site or in proximity thereof. Two samples were taken by dissolving unburnt bricks from production sites along

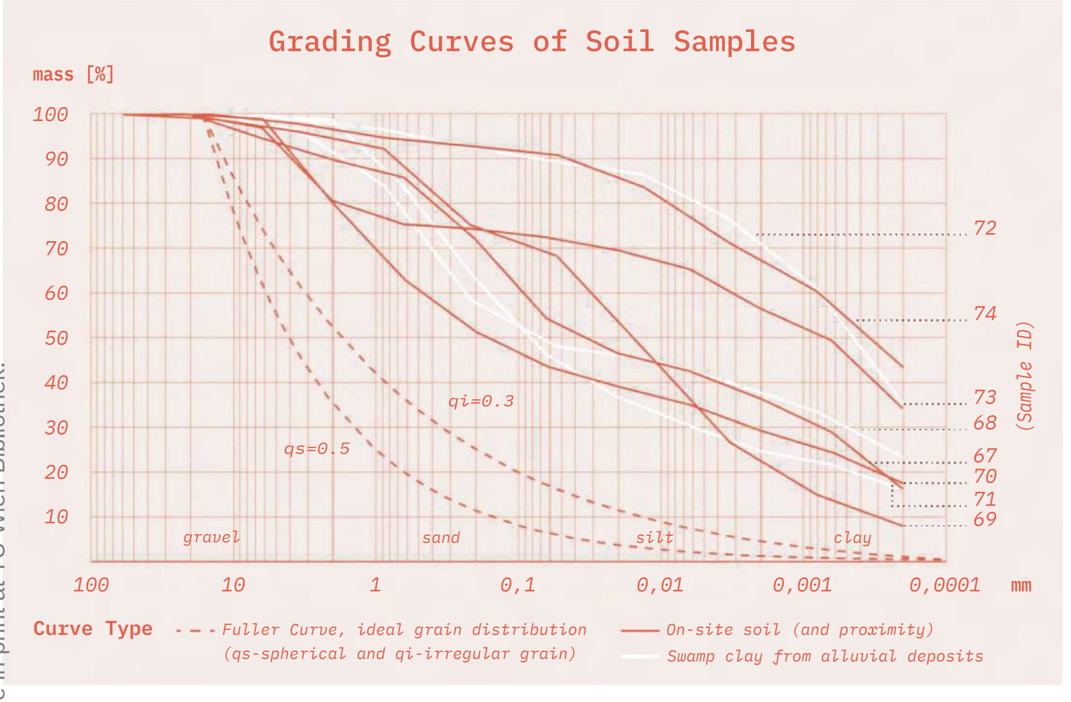


fig.2 Grading curves, i.e. grain size distribution of the different soil samples.

the Nakaseke-Wobulenzi road (68 and 71) to get an idea of the raw material composition of locally produced bricks. Finally, one sample (72) was excavated from a depression in a swampy area close by one of the brick kilns, where slack water had already accumulated. We rightly assumed that this material could serve as a sealing layer in the constructive wetland, but at the same time wrongly hoped for some potential for the production of clay plaster. The three samples taken from the swamps further away come from alluvial deposits, while the mineral composition of the samples on site can be attributed to laterite deposits or, more generally, local weathering processes.[3]

Interpreting the Results

Since the cohesion of clay minerals is based on electrostatic force and not on chemical processes that change the structure of the material,[4] building materials that use clay as a binding agent can be fully recycled. For the same reason, the cohesive force of earthen building materials, is often weaker than that of industrial materials, which makes the adequate composition even more important. There are two main factors that affect adhesive strength materials that use clay as a binder: grain size distribution and composition of the clay fraction.

Fig.1 shows the grading curves of all soil samples. The x-axis of the graph indicates the grain size and the y-axis the corresponding mass fraction. Clay minerals fall within the initial spectrum of the x-axis in the range of 0-2 μm. Fractions larger than 2 μm are called silts and sands. As a means of interpretation, grading curves are compared to the Fuller curve for an ideal grain size distribution, in which the void between different grains is minimized. Ideal grain size distribution is calculated by following formula:[5]

$$A(d)=(d/d_{max})q$$

with A(d) being the cumulative percentage of the mass of a sample passing a sieve with aperture diameter d, d_{max} the maximum diameter of aggregate particles and q the grain size exponent, determined as q=0,5 for an ideal, spherical grain shape,[6] and q=0,3 for irregularly shaped, broken sand and gravel.[7] The closer the measured data plots to the Fuller curves, the more well-graded the samples are.

Clay Mineral Analysis

Clay Mineral	Sample ID [205]67	["]68	["]69	["]70	["]71	["]72	["]73	["]74
Smectite/ Vermiculite	traces	4 %	45 %	0 %	7 %	51 %	traces	1 %
Illite	16 %	44 %	traces	8 %	3 %	3 %	6 %	6 %
Kaolinite	84 %	52 %	55 %	92 %	90 %	46 %	94 %	93 %

tab.2 Clay mineral analysis results.

The two Fuller curves show a clay content of 2% and 5% respectively, with the remaining percentage being silt and sand. In comparison, the grading curves show that all samples have remarkably high clay contents, ranging from about 22% for sample 69 to 70% for sample 72. The overall high clay content explains the severe cracking in all field tests and the need to modify the grain size distribution. However, the field tests also showed that the addition of mineral aggregate alone is not sufficient in this particular case, which brings us to the second factor, the composition of the clay fraction.

Just as a soil sample can be divided into different grain sizes, there is also a size range within the smallest fraction. As small clay minerals have a greater total surface area than large clay minerals, they can hold larger amounts of water. The capacity to bind water results in enhanced cohesive forces, accompanied by augmented swelling and associated cracking during the drying process.

Tab. 2 shows that the largest part of clay minerals in most samples consists of kaolinite, with a smaller portion of illite. The particle size of both illite and kaolinite is within the medium to coarse clay range, with correspondingly low cohesive forces. Especially the clay in the soil samples from the surface of Bowa Hill (67, 70, 73, 74) consists almost exclusively of kaolinite, the mineral with the lowest cohesive force. Although the cohesive forces and swelling behavior of kaolinite are relatively low, the high total amount of clay increases both properties in proportion to one another. This phenomenon corresponds to the dilemma we encountered during our clay experiments. Working with the on-site material, mixes with little mineral aggregate showed sufficient cohesion with significant cracking, while leaner mixes with more aggregate lost cohesion and showed little resistance to abrasion. In contrast, the two samples from the alluvial deposits consist mostly of very fine smectite and vermiculite of high cohesion and dilative properties. Even in a very lean mixture with a large parts of unwashed sand as aggregate, no usable earthen materials could be achieved.

Clay as a Building Material

The analysis of clay minerals confirms that none of the samples can produce qualitative building materials with mineral aggregate alone. Sample 72 (Swamp Clay) from alluvial deposits is not suitable as a building material but could serve as an earthen sealing for both foundations or the constructed wetland due to its high dilative properties. Further experiments are taking place on site.

To optimize cohesion, different soils from both on-site and alluvial deposits could be mixed, while additional mineral aggregate would reduce the overall clay content. However, the resulting increase in transportation would have a negative impact on CO_2 emissions and costs, which would contradict the idea of universal applicability. As every modification directly translates to an increased environmental impact, it is only at an industrial scale of production that such an effort could create relevant alternatives to building materials of even higher energy input.

Another common method of modifying the properties of earthen building materials is the addition of fibers. Compared to mineral aggregate, fibers are better at reducing cracking,

Transportation Distances to Bowa Hill

Location	Asphalt Road	Earth Road	Path	Total Distance
Wobulenzi	2,7 km	17,6 km	1,4 km	21,7 km
Katikamu	-	17,6 km	1,4 km	19,0 km
Lumansi Swamp	-	13,9 km	1,4 km	15,3 km
Nakawunge	-	7,7 km	1,4 km	9,1 km
Kikwanda Quarry	-	7,3 km	1,4 km	8,7 km
Timuana	-	5,5 km	1,4 km	6,9 km
Nakaseke	-	4,4 km	1,4 km	5,8 km
Rachel's Garden	-	2,6 km	1,8 km	4,4 km

The map includes the main traffic routes and the roads and paths essential for transportation.

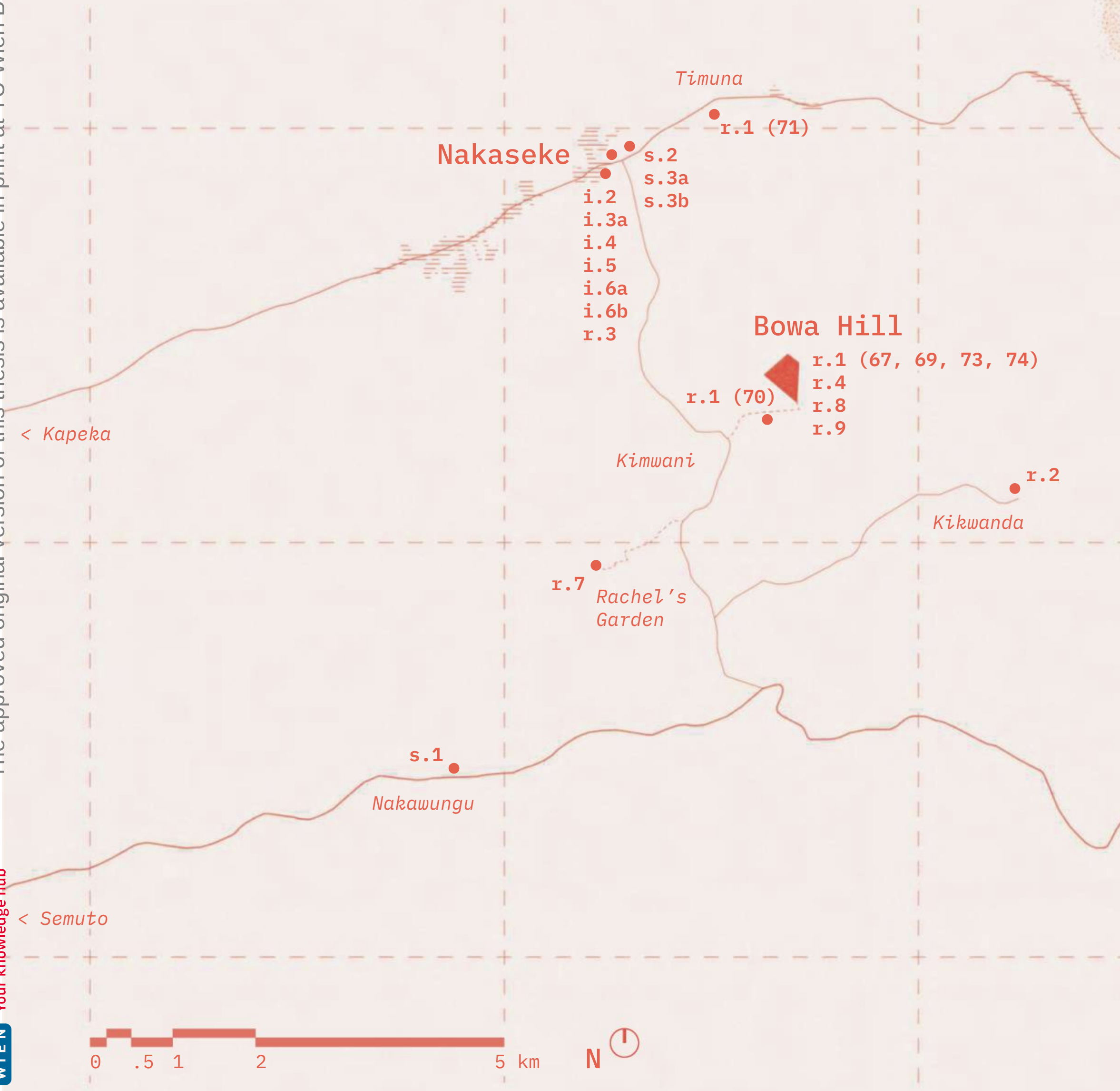
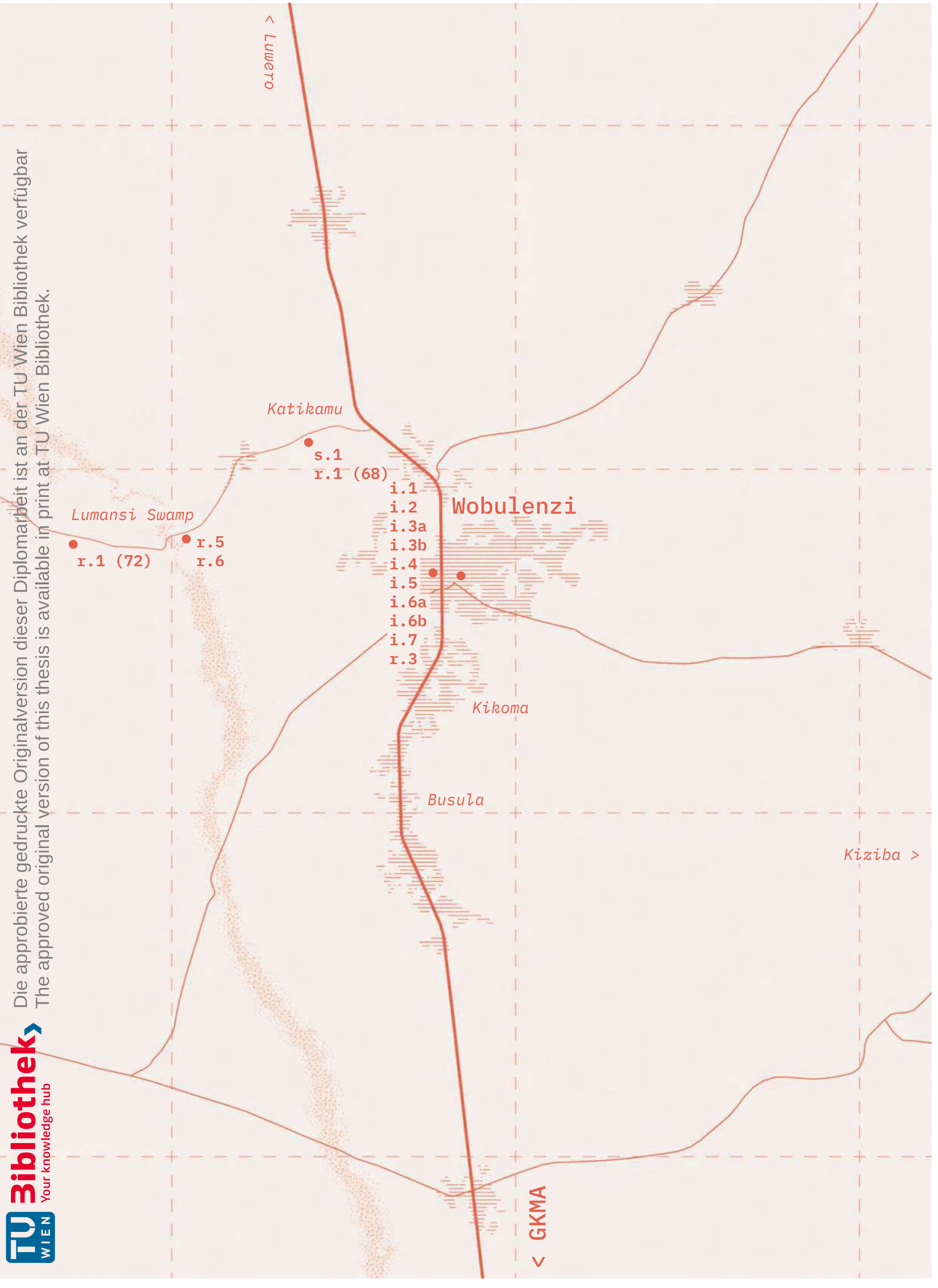


fig.3 Material allocation map of the immediate project region.


Luwero >
Katikamu
s.1
r.1 (68)
i.1
i.2
i.3a
i.3b
i.4
i.5
i.6a
i.6b
i.7
r.3
Wobulenzi
Lumansi Swamp
r.1 (72)
r.5
r.6
Kikoma
Busula
Kiziba >
< GKMA

which in the case of the samples presented above, would result in a lower total amount of aggregate required. At the same time fibers are significantly lighter than most mineral materials, facilitating transportation without the necessity of vehicles, even in large quantities. Finally, as a byproduct of agricultural products, fibers have minimal, if any, monetary value.

As mentioned in the construction diary, we were not able to find suitable fibers during the building workshop, but since a large part of the population of the Central Region is involved in agriculture in one way or another, it can be assumed that fibrous aggregates are generally available. Such fibers include animal hair or dung, sawdust, straw, hemp or flax shives, and the fine seeds of the typha (bulrush) plant that grows in swamps.

Material Culture

In the research chapter on common practices, we postulated that the contemporary vernacular, like the traditional Kiganda, "can be seen as the closest possible approximation of the ideal home, depending on the financial means of the owner, with the status value being determined primarily by the novelty value of the materials used and the money spent."[8] As the material culture of a society is always an expression of collective values, the phenomenon described above is by no means context-specific, but rather global. Even though, or exactly because, from an economical point of view, natural building materials are more cost-efficient for small-scale residential buildings, there is a widespread cultural expectation for houses to be constructed with industrial materials[9]. Accordingly, the social (and often political) acceptance for traditional building materials and techniques is low.[10] During our field trip, this low status value was expressed in a prevailing image of buildings made from renewable resources as being of poor quality and with a presumably short lifespan. Yet our experience also shows that the cause of poor quality is usually not the material itself, but rather the way it is handled.

1 Mass, B. (2024) *For Example Bowa Hill - On the Transformation of Contemporary Vernacular Architecture: Thermal Comfort and Environment*, p. 19. Vienna: Vienna University of Technology.
2 Weber, S., Spörk, T. (2022) *Konstruktives Projekt. Materialanalyse für den Lehmbau in Uganda*. Vienna: BOKU
3 Lehto et al. (2014) *Geological Map of Uganda, Scale 1:1 000 000*. Espoo, Finland: Geological Survey of Finland.
4 Röhlen, U., Ziegert, C. (2020) *Lehmbau-Praxis. Planung und Ausführung. Deutsches Institut für Normung*, Wien: Beuth Verlag.
5 Fuller, W.B., Thompson S.E. (1907) 'The laws of proportioning concrete'. *Transactions of the American Society of Civil Engineers*, 33 (1907):222–298.
6 Ibid.
7 Weber, R., Riechers, H.-J. (2003) *Kies und Sand für Beton*. Düsseldorf: Verlag Bau+Technik GmbH, (after Wesche, K. (1993) *Baustoffe für tragende Bauteile. Band 2: Beton, Mauerwerk*, Wiesbaden: Vieweg + Teubner).
8 Weidacher, M. (2024) *For Example Bowa Hill - On the Transformation of Contemporary Vernacular Architecture: Building Culture and Materials*, pp. 84. Vienna: Vienna University of Technology.
9 Sanya, T. (2007) *Living in Earth. The Sustainability of Earth Architecture in Uganda*, pp. 93. Oslo: The Oslo School of Architecture and Design.
10 Ibid., pp. 197

Life Cycle Assessment Qualitative Evaluation

Benedikt Mass

A comprehensive life cycle assessment (LCA) is the second part of this evaluation. The aim of this quantitative analysis is to identify which building components have the highest potential for emissions reduction, which measures taken in the project were most effective, and where further improvements can be implemented. In parts, the following text differs significantly from the previous chapters, as life cycle assessments follows a standardised structure and therefore established conventions.

A Construction Kit

In preparation for further investigations, an inventory of different building components based on materials from the previous chapter and our experience on site was complied.[1] Intended as a construction kit, the inventory provides information on the environmental impact of the building components per functional unit (i.e., the impact per square meter of building component) and allows for the exemplary assessment of buildings assembled from any combination of components. The kit only includes materials that seem relevant for both building construction (based on our research and construction experience) as well as the environmental footprint of a building. Roofs with ceramic tiling for example are not included in the evaluation for the fact that they are neither economically feasible nor available in rural areas. Furthermore, miscellaneous small quantities of building materials (plastic sheets, geo-membrames, washers etc.) have been excluded since their environmental impact is negligible. Fig.1 on the following double page gives an overview of the available materials on the left, from which the different building components on the right can be assembled. In many cases an additional step of an intermediate product is required, such as the firing of bricks or the mixing of mortar and plaster to build a wall.

The availability of different materials or variations in production processes of some intermediate products, like fired or unfired bricks and clay, cement or lime for the production of mortar and plaster, means that some building components allow for different alterations depending on the type of brick, mortar or plaster used. A simplified flow diagram for the production of a conventional brick wall (W1a) is visualized in fig.1 as an example. In a second step, three proxy buildings were defined based on the geometry of the case study building House 1, which was also used for the thermal comfort assessments in the pre-design chapter. Proxy 1 represents the contemporary vernacular typology, fully constructed of industrial and semi-industrial materials, Proxy 2 corresponds to the hybrid construction of the case study buildings on Bowa Hill, and Proxy 3 is a fictitious, improved building construction with what we judge to be the maximum content of materials with low environmental impact. The combination of building components for the three different proxy buildings is shown in fig.2. While Proxy 2 represents the process of our applied research and Proxy 1 and 3 define the range of the environmental impact of a model building in our specific context, other combinations of building components with different, possibly even improved, environmental impact can be conceived from the initial material toolkit.

The results of the corresponding life cycle assessments are compared towards the end of this chapter for both individual components as well as the full building proxies. The comparative assessment excludes plumbing and electrical fixtures. The full inventory of different building components and the quantity of necessary material inputs for their production is included in the results section. While all upstream process chains and material inputs for the production of industrial building materials are included in the life cycle assessment of each component, the appendices do not include a detailed overview of these preliminary material flows for the sake of simplicity.

Construction Kit

Building Material	*Intermediate Product (produced on site or close by)*

Renewable

r1 clay soil
r2 gravel
r3 sand
r4 flagstone
r5 speargrass (essubi)
r6 papyrus stalks
r7 elephant grass (emuli)
r8 water
r9 banana fiber

Semi-industrial*

s1 fired clay brick r2 gravel
s2 round timber (eucalyptus)
s3a sawn timber (muvule)
s3b sawn timber (unspecific)

Industrial*

i1 lime
i2 portland cement
i3a galvanized steel sheets
i3b powder coated steel sheets
i4 reinforcement steel
i5 steel wire mesh
i6a steel nails
i6b galvanized steel nails
i7 window glazing

clay mortar/plaster

unfired clay brick

fired clay brick

cement mortar/plaster

concrete lintels/screed

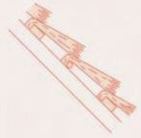
*industrial and semi-industrial building materials are intermediate products in themselves, as they are pre-processed from primary ressources to varying degrees. The environmental impact of the process chain is already included in the material. In addition, the materials are purchased in a condition that can be used directly on site and do not need to be further processed. They are therefore listed on the material input level.

fig.1 The Construction Kit; building materials, intermediate products and building components.

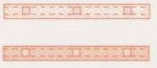
Building Component | *Abbreviation*

Roof
- *R1 metal roof*
- *R2 thatched roof*

R1

R2


Ceiling
- *C1a conventional ceiling, concrete plaster*
- *C1b conventional ceiling, clay plaster*
- *C2 conventional ceiling, clay plaster, insulation*
- *C3 papyrus/emuli ceiling, clay plaster*

C1


C2

C3


Lintels/tie-beams
- *L1 concrete tie-beam*
- *L2 wooden lintels*

L1

L2

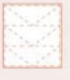

Walls (& foundations)
- *W1a brick wall, cement mortar & plaster*
- *W1b brick wall, cement mortar, clay/lime plaster*
- *W1c brick wall, clay mortar & plaster*
- *W2 brick wall unfired, clay mortar & plaster*
- *W3 wattle-and-daub wall*

W1


W2

W3


Windows/doors
- *O1 steel windows*
- *O2 steel doors*

O1

O2


Floor
- *F1 concrete floor*
- *F2 rammed-earth floor*
- *F3 stone floor*

F1

F2

F3

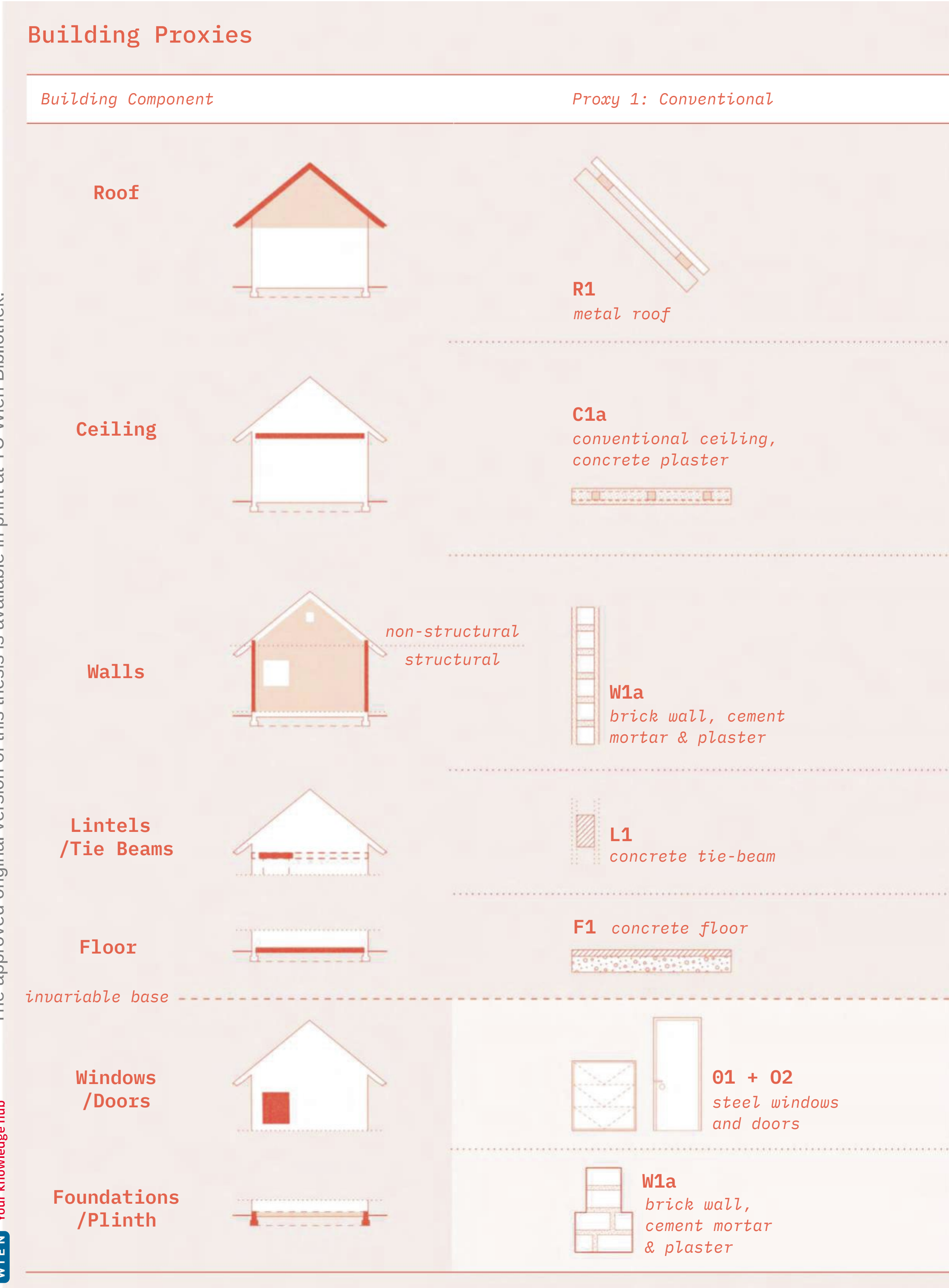
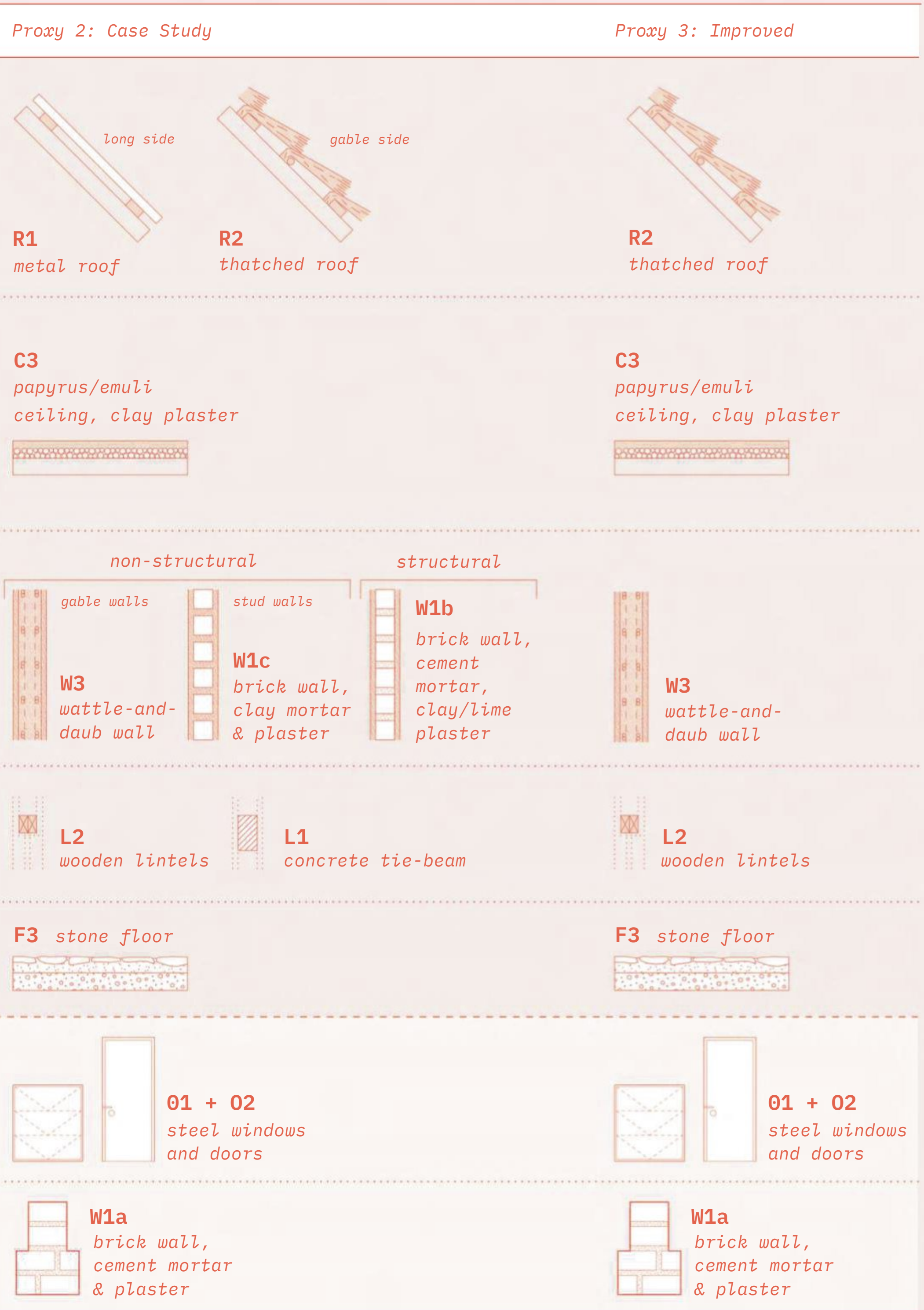



fig.2 Building proxies; assembling three buildings with components of the construction kit.


Proxy 2: Case Study
Proxy 3: Improved
long side
R1
metal roof
gable side
R2
thatched roof
R2
thatched roof
C3
papyrus/emuli
ceiling, clay plaster
C3
papyrus/emuli
ceiling, clay plaster
non-structural
structural
gable walls
W3
wattle-and-
daub wall
stud walls
W1c
brick wall,
clay mortar
& plaster
W1b
brick wall,
cement
mortar,
clay/lime
plaster
W3
wattle-and-
daub wall
L2
wooden lintels
L1
concrete tie-beam
L2
wooden lintels
F3 stone floor
F3 stone floor
O1 + O2
steel windows
and doors
O1 + O2
steel windows
and doors
W1a
brick wall,
cement mortar
& plaster
W1a
brick wall,
cement mortar
& plaster

Methodology

Life cycle assessment (LCA) is the most common approach to determine environmental effects caused by any specific product or system. The life cycle assessment can be limited to the production, or part of the production, of a product, i.e., cradle-to-gate or gate-to-gate, respectively. A more comprehensive approach is to evaluate the impact of a product throughout its whole life cycle including its end-of-life, sometimes further differentiating between disposal, reuse, and recycling processes, i.e. cradle-to-grave or cradle-to-cradle.[2]

The software used for the following lifecycle assessment is openLCA[3], an open-source, free to use software developed since 2006, that integrates several validated free and commercial databases provided by the EU, NGOs and scientific institutions as well as a large number of different life cycle impact assessment (LCIA) methods. The software was chosen based on evaluations of different LCA software solutions[4,5] for its non-commercial availability, its versatility and user-friendly interface.

In its methodology, the life cycle assessment (LCA) follows the ISO 14044:2006/Amd.2:2020 guidelines[6,7] and is structured into four work steps:

- The goal and scope definition of the LCA
- The life cycle inventory analysis (LCI) phase (data collection and evaluation)
- The life cycle impact assessment (LCIA) phase (based on the preceding LCI)
- The life cycle interpretation phase, where limitations of the LCA are identified, results are compiled after critical review, and recommendations for future reference given based on these results.

Goal and Scope

Both single building components from the inventory as well as the three complete proxy buildings are evaluated in order to assess their environmental impact for future reference.

The goal and purpose of the LCA is a comparative assessment of the environmental impact of conventional building components with more sustainable alternatives, both in direct comparison by functional unit as well as by comparison of cumulative results for three building proxies composed of different quantities of building materials and components. The three building proxies are derived from the same geometry - that of the case study building House 1 as constructed on Bowa Hill. In this way, those building components with the highest potential for environmental impact reduction can be identified as a basis for future decisions regarding the construction of (non-engineered) small-scale residential construction.

The functional unit of the different building materials and components is 1 square meter, meter (lintels and tie-beams) or cubic meter (foundations), respectively. The results presented for each component are based on this functional unit. The cumulative results for the three building proxies are compiled as absolute values for the complete buildings, comprised of the different quantities of different building components as derived from the geometry of case study building House 1.

The LCA follows a cradle-to-gate approach, i.e. the environmental footprint up until the completion of construction activities is being accounted for. This means the LCA includes all upstream processes starting from the extraction of primary resources. All processes contributing significantly (primary resource extraction, production, transport, packaging…) to the environmental impact are taken into consideration, including production and maintenance of necessary manufacturing facilities and machinery, where applicable. Tools and small machinery (hammers, hacksaws, etc.) and materials used in minor quantities (rubber washers, PVC film) are not included as upstream processes, as their contribution to the results is considered negligible. The system boundaries for the LCA results therefore are confined to a timespan that ends when building construction is completed, and the buildings' environmental footprint neither includes the environmental impact of building maintenance, nor demolition and disposal or recycling of building materials. It is important to note, that this decision is not taken for reasons of convenience. Even only a rough estimation of these impacts would exceed the scope of this study, particularly in the context of Uganda, with an informal economic system for which no reliable data concerning these issues exists. However, the end-of-life of building constructions and the circularity of building materials and components is briefly addressed in the interpretation of results and again in the final chapter of the book.

Life Cycle Inventory (LCI) analysis

The ecoinvent V3.8 database[8] was used as the primary source for input data for the LCI. As a commercial database, it provides validated data sources for an extensive range of processes across all economic sectors from raw material extraction to the rendition of administrative services. However, comprehensive country-specific data exists only for Europe and, for specific sectors, other large and emerging economies like the US, Canada, China, India, Russia, or Brazil.

Where no country-specific data is available, like it is the case for Uganda, the database provides international mean values. Such mean values are labelled as RoW (Rest of the World) and serve as an approximation to be worked with. However, data inputs and outputs of these internationally aggregated processes do not always adequately represent local circumstances in Uganda. In this case, country-specific processes from countries with comparable standards and economical profiles in the respective sectors were used when applicable (e.g. for the transport sector, data for unregulated South-African road transport was used in the LCI). Where no appropriate substitute processes were available, processes were modified, or new process chains were created according to on-site research and additional literature research. Adapted processes mainly apply to reducing industrial manufacturing processes in favour of manual labour, modes and distances of transportation, and the use of fuel wood instead of fossil resources.

For all necessary electrical energy inputs, internationally aggregated data for electricity production and supply was used when compiling the LCI. The issue of uncertainties regarding data input is addressed below in the section titled Uncertainty and Sensitivity Analysis.

Life Cycle Impact Assessment (LCIA)

Many different life cycle impact assessment (LCIA) methods with varying mid- and endpoint categories and different weighting approaches for results calculation exist, so an appropriate LCIA method should be chosen according to the goal and scope of the LCA. For further reference, You and Su[9] give a detailed account of most common LCIA methods. LCIA results can be calculated for both mid- and endpoint impact categories. Midpoint impact categories yield a direct result for a single indicator, while endpoint impact categories provide aggregated results in the form of a "score" calculated from several midpoint indicators, multiplied with individual weighting factors defined in the methodological approach of the respective LCIA method. This means that an LCIA method may include for example midpoint category indicators for global warming potential (as kg CO2-eq) and human non-carcinogenic toxicity (as kg 1,4-DCB-eq). Both indicators may then be grouped together with other indicators to contribute to an overall score for an endpoint impact category indicator for human health. Depending on whether the LCIA method focuses more on immediate than on long-term effects on human health, for instance, human non-carcinogenic toxicity may be assigned with a higher weighting factor than climate change, whose effects on human health may be devastating to the whole human population in the long term but may have little immediate effects on individuals in specific circumstances.

For the life cycle impact assessment (LCIA) the ReCiPe2016 hierarchical midpoint assessment method[10] was chosen in favour of other methods, as it includes the most suitable midpoint impact category indicators for the goal of this LCA. Unlike an endpoint assessment, the midpoint assessment method allows individual results to be presented for multiple impact categories, which can then be individually grouped or aggregated, while excluding less relevant categories or categories with too many input uncertainties. The parameters shown in Tab.1 on the following page were chosen as indicators for the comparative assessment of the different building constructions.

Impact Categories

The choice of impact factors is based on several assumptions regarding prospective readers. Firstly, global warming potential, acidification potential and, to lesser extent, ozone formation (emissions of NOx-eq) are commonly used indicators (e.g., in the Austrian OI3-Index) for the environmental impact of materials and therefore presumably most comprehensible to a wider audience. Secondly, aggregated values for ecotoxicity and human toxicity have been included in the LCA results to indicate the magnitude of more immediate impacts of the analysed building constructions on human health and environmental integrity.

While the implications of greenhouse gas emissions (kg CO2-eq) do not need additional explanation due to high public awareness regarding climate change issues, further elaboration may be needed for the other impact category indicators, since their measuring units may not be a tangible quantity to the imagination and background knowledge of some readers, or most, as in the case of 1,4-Dichlorbenzene-equivalent.

Sulphur dioxide (SO2) is a major air polutant, harmful to the respiratory system and the main constituent of acid rain, which has damaging effects on forestal and aquatic ecosystems due to its phytotoxic properties.[11]

Increased concentration of nitrogen oxides (NOx) negatively affects the human respiratory system, especially in the long term. Furthermore, nitrogen oxides are a precursor for several harmful secondary air pollutants like nitric acid (another constituent of acid rain) and photo oxidants including ozone.[12]

1,4-Dichlorbenzene (1,4-DCB) is a known carcinogenic agent and can cause blood and organ damage in cases of long-time exposure. For a better understanding of the magnitude of its impact, additional contextualization seems advisable. Regarding short-term toxicity, the LD50 concentration – i.e., 50% lethality in exposed population – for one-time exposure by oral ingestion was measured at 500 mg per kg of body weight in mice.[13] In workplace environments, a maximum average concentration of 12 mg/m³, with short-time peak values of 60 mg/m³ is considered non-hazardous by EU regulations for airborne concentrations,[14] while in emissions from manufacturing plants or other operational facilities in Germany, the concentration of 1,4-DCB must not surpass a mass flow of 0,1 kg/h or a concentration of 20 mg/m³.[15] In aquatic ecosystems, a PNEC (Predicted No Effect Concentration) of 20µg/l is extrapolated from the NOEC (No Observed Effect Concentration) for fish, which lies at 0.2 mg/l, while in terrestrial ecosystems, extrapolation from the LC50 of earthworms (96 mg/kg dry weight) results in a PNEC of 96 µg/kg dw.[16] As illustrated in the research chapters, excessive land use, environmental degradation, soil depletion, erosion and recurring droughts aggravated by climate change are of increasingly problematic scale in Uganda. Since the available input data that significantly influence the results for these and other remaining impact category indicators is either incomplete or unreliable, and aggregated international data values neither seem to fit the particular circumstances in Uganda, further impact category indicators were excluded from the LCA. To still account for these problems, deforestation as one of the major issues regarding environmental degradation, soil erosion and depletion of biodiversity is addressed separately, albeit briefly, in the interpretation of results, in the context of wood use in building construction and as fuel wood for artisanal brick kilns.

Uncertainty and sensitivity analysis

For the simple reason that to this point, no specific research regarding neither life-cycle data nor data uncertainties for the geographical context of Uganda is known to the authors, no comprehensive uncertainty analysis was conducted for the life cycle assessments and it was assumed that for processes used directly from the ecoinvent database, provided globally aggregated values and their assigned uncertainty factors also apply for the case of Uganda. As for all adapted or newly created processes, no reliable uncertainty factors can be assigned without exceeding the scope of this study, so any uncertainty analysis conducted, regardless of its methodology would not yield meaningful results. This means that all values presented in

Midpoint Impact Categories & Related Indicators

Midpoint Impact	Indicator	CF_m*	Unit
Climate change	Infrared radiative forcing increase	Global warming potential (GWP)	kg CO_2-eq to air
Terrestrial acidification	Proton increase in natural soils	Terrestrial acidification potential (TAP)	kg SO2-eq to air
Photochemical oxidant formation: terrestrial ecosystems	Tropospheric ozone increase	Photochemical oxidant formation potential: ecosystems (EOFP)	kg NOx-eq to air
Human toxicity (aggregated)		**Human toxicity potential (HTP)**	kg 1,4-DCB-eq to urban air
Human toxicity: cancer	Risk increase of cancer disease incidence	Human toxicity potential (HTPc)	kg 1,4-DCB-eq to urban air
Human toxicity: non-cancer	Risk increase of non-cancer disease incidence	Human toxicity potential (HTPnc)	kg 1,4-DCB-eq to urban air
Ecotoxicity (aggregated)		**Ecotoxicity potential**	kg 1,4-DCB-eq
Terrestrial ecotoxicity	Hazard-weighted increase in natural soils	Terrestrial eco-toxicity potential (TETP)	kg 1,4-DCB-eq to industrial soil
Freshwater ecotoxicity	Hazard-weighted increase in freshwaters	Freshwater eco-toxicity potential (FETP)	kg 1,4-DCB-eq to freshwater
Marine ecotoxicity	Hazard-weighted increase in marine water	Marine ecotoxicity potential (METP)	kg 1,4-DCB-eq to marine water

* Midpoint characterisation factors

tab.1 Relevant midpoint impact categories and related indicators.[12]

the LCA results below must be seen as indicative only, and that further empirical research in this direction would be necessary to generate more accurate results. However still, areas and processes with the largest uncertainties from the point of view of data collection were identified and local sensitivity analyses conducted to understand the order of magnitude of uncertainties. This concerns mainly three areas, where inputs are not of fully satisfactory quality:

i) All processes where electrical energy production and supply are significant input processes either directly or in upstream processes. This applies mainly to metal and steel products used on site, since most other processes require little to no electrical energy input, especially in the specific context of small residential buildings in Uganda, where most production processes rely heavily on manual labour. While the largest share of Uganda's electrical supply is produced by hydropower stations, no complete data for neither the country's energy production mix, including the types and efficiency of electrical plants, nor the electrical supply and distribution grid could be obtained, however. Therefore, the use of aggregated international mean values for electricity production and supply was favoured in the LCI over the model of a national electricity market based on potentially significantly wrong assumptions, even though it is known that the share of fossil, nuclear, wind and solar power is significantly higher in an international energy mix, while that of hydropower is significantly lower. It should be kept in mind that emission outputs related to electricity production and supply are therefore different from those that an accurate model of the national electricity supply would yield, even if the magnitude of the difference has not been quantified.

ii) All processes requiring inputs related to silviculture and forestry, like timber production and use of firewood. In Uganda, timber is sourced either from natural or untended forests, regardless of environmental regulations, or from plantations with varying degrees of sustainable management and industrialization. Data could neither be obtained regarding the share of plantation wood in timber production,

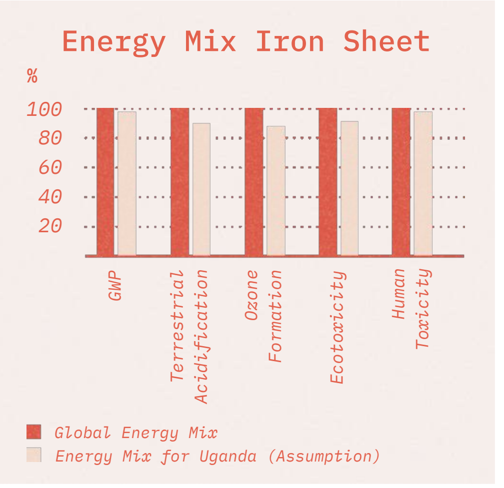


fig.3 (above) Sensitivity analysis results for energy use.
fig.4 (below) Sensitivity analysis results for wood products.

nor on the share of manual and industrialized labour (i.e., the use of heavy machinery) in the timber production chain. Therefore, only crude and to some extent biased assumptions based on field observations could be made regarding the production of wood products.

iii) The energy demand in form of fuel wood for artisanal brick kilns. While the brickmaking process was modelled with considerable accuracy following the thorough LCI conducted in a comprehensive study on the South African brick production industry,[17] some uncertainty arises from the different energy input in Ugandan brick kilns. Since the examined clamp kilns in South Africa are larger, more effective and use coal as an energy source, the energy input had to be adapted to fit the energy demand of smaller, artisanal brick kilns using wood combustion as their only energy source. As research on the energy demand of this type of brick kilns is scarce, no empirically measured values were available, and estimated values from Hashemi and Cruickshank[18] were used as a basis for the LCI.

Local sensitivity analyses have been conducted regarding the uncertainties in data collection identified above. For the example of metal sheets used as a roofing material, the impact of the electricity mix on overall results has been evaluated by comparing results for sheets with an internationally aggregated electricity mix with the assumed energy mix for Uganda. As a reference for the supply and distribution network, data for the neighbouring country of Kenya from the ecoinvent database was used. Fig.3 shows that results do not differ significantly for both systems.

Similarly, as shown in fig.4, the results for wood products from commercial plantations do not change significantly whether manual labor or heavier machinery is used, since the largest share of emissions comes from the production and use of fertilizers and pesticides, regardless of their mode of application. By comparison, wood from unregulated logging performs significantly better in the selected impact categories, which once again do not adequately address other environmental issues such as deforestation and related secondary problems. Additionally, since wood products have comparatively low emission results and are used in relatively small quantities in all proposed building components, the provenience of wood products still does not significantly influence the overall results of the comparative life cycle assessments. Emission results for brick production are directly proportional to the amount of fuelwood used per functional unit, and therefore differ accordingly if the input amount is changed.

Life Cycle Interpretation and Results

Below, results for both the individual building components as well as the three building proxies as defined in fig.1 and fig.2 are discussed separately, with a focus on global warming potential as the most tangible parameter to both compare the range of their environmental impact as well as to place them inside a broader context.

Firstly, the life cycle assessment results for the individual building components are compared. In the graphs in fig.5 on the next page, the LCA results for the different building components are shown as a function of the conventional components with industrial materials. Since their environmental footprints are the largest, they serve as reference for the more sustainable alternatives. As the latter results are scaled as a percentage of the conventional constructions, the environmental impact reduction potential for each alteration of a specific building component can be intuitively understood. Since this does not take into account how the different components compare to each other - e.g. how the environmental impact of any roof compares to that of any wall construction - the results are discussed in absolute numerical values as well. As an additional overview, tab.4 lists these absolute results for all building components in all five impact categories. For informative purposes, a list of the quantitative material inputs necessary for the production of one functional unit of each building component and intermediate product is included in tab.2 and 3. Secondly, the comprehensive LCA results for the building proxies are discussed. Results are summarized in fig.6 and tab.5 in a similar way as the results for the individual components.

Assessment of Building Components

Unsurprisingly, the potential for environmental footprint reduction by substituting conventional materials with sustainable alternatives is huge, as all constructions with sustainable materials only produce a fraction of the emissions of its industrial counterparts. However, not all constructions are equally feasible, and some building components disproportionately affect the ecological footprint of the whole building, as will be shown in the results of the LCA for the complete buildings. The results presented below serve as a basis for the final thoughts on contemporary small-scale non-engineered structures in the following chapter.

Roof

The LCA compares a roof with metal sheathing to a grass-thatched roof. While a ceramic roof construction was still part of our parametric thermal comfort simulations in the pre-design phase, it was excluded from this evalution due to its lack of both local availability and economical feasibility, as has been explained above. Only coated steel sheets have been considered for the conventional roof construction in the LCA. While aluminium sheets are available to some extent, they usually need to be shipped from the greater Kampala area. Steel has a smaller ecological footprint than aluminium (e.g. 12.5 kg CO_2eq per m² vs. 15.3 kg CO_2eq per m²)[18,19], however the life span of aluminium sheets is considerably longer, thus compensating for the higher emissions to some extent. The global warming potential of the metal roof lies at 24.63 kg CO_2eq, as compared to 2.56 kg CO_2eq for the thatched roof. Therefore, the environmental impact reduction potential per square meter of building component is the second to highest, exceeded only by the impact reduction potential per square meter of wall construction.

Ceiling

In conventional ceiling constructions, the largest emissions reduction potential lies in substituting cement with clay plaster. Metal wire mesh used as a plaster base is the second largest contributor to the ecological footprint. However, replacing it with a sustainable substitute from plant fibre may prove difficult, and cause a significantly higher amount of manual labour. Of the natural materials available on site, none yielded satisfactory results as a plaster base. Eventually, papyrus stalks visible from below were used on site as an alternative, covered by clay plaster from the top. If tightly packed and layered, papyrus also provides excellent insulation from the heat emanating from the roofing sheets. If cementitious plaster can be replaced by natural plasters made from clay soils, the global warming potential can be reduced from 17.89 kg CO_2eq to 2.91 kg CO_2eq. If the wire mesh used as a plaster base is substituted by renewable fibrous material, it further reduces emissions to 0.59 kg CO_2eq.

Walls

In conventional plastered brick walls constructed like they are in Uganda – with a running bond and mortar joints up to 5 cm wide – the volume ratio between bricks and cementitious material (mortar and plaster) can be up to 1:1. Correspondingly, the potential to reduce the environmental footprint by replacing cement with clay materials is high. By using clay plaster on the interior, and lime plaster on the exterior side, for instance, the global warming potential of 61.61 kg CO_2eq can be reduced by a third to 40.80 kg CO_2eq, and by almost two-thirds, to 21.00 kg CO_2eq, if mortar is also replaced. Still, they cannot compete with the environmental footprint of wattle-and-daub building techniques (1.71 kg CO_2eq) or massive walls from unfired clay materials (1.49 kg CO_2eq), which is only a fraction of that of any wall with fired bricks. Roughly estimated, 10% of bricks are destroyed during transport already or not suitable for construction due to poor quality. While the LCA results do not account for these material losses, they pose a problem in the use of unfired clay bricks if they cannot be produced on site, as their considerably lower shock resistance makes their transport on the poor Ugandan roads virtually impossible.

Floors

In concrete floors, secondary aggregates are widely used. Gravel is often replaced by brick residue from construction work. While this is an economical and resource-friendly alternative, it only influences LCA results by 2 to 4% for different impact categories. Therefore, no separate results are shown for this substitute. The more sustainable alternatives presented are rammed earth floors and the floor construction used in the project, with natural stone flooring from on-site material with mortar joints. While the latter has the highest ecological footprint of all alternative floor constructions, its results still only range from 32% for global warming potential (5.23 vs. 16.28 kg CO_2eq in total numbers) to 47% for human toxicity, as compared to those for a concrete floor. However, the environmental footprint of stone floors is strongly dependent on the

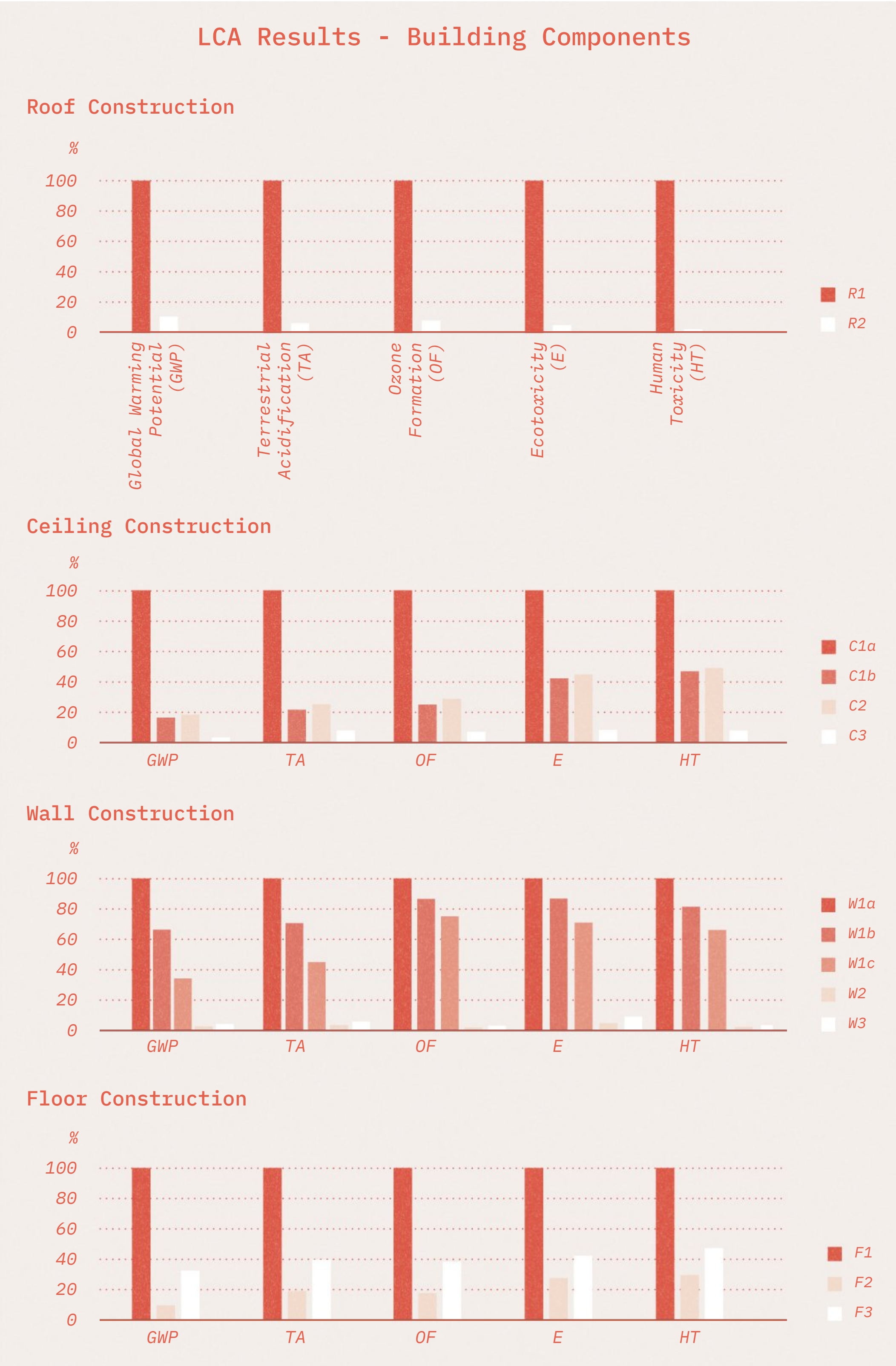


fig.5 Comparison of LCA results for the different building components.

Building Components

Component / Input	Amount	Unit
F1 - Concrete Flooring	**1**	**m²**
cement mortar, hand-mixed on site	62,4	kg
gravel, crushed	54	kg
transport, freight, lorry 3.5-7.5 metric ton	0,54	t*km
F2 - Rammed earth floor	**1**	**m²**
clay extraction from site	72	kg
gravel, crushed	144	kg
transport, freight, lorry 3.5-7.5 metric ton	1,44	t*km
F3 - Flagstone Floor	**1**	**m²**
cement mortar, hand-mixed on site	15,6	kg
granite	63	kg
gravel, crushed	108	kg
sand	64	kg
transport, freight, lorry 3.5-7.5 metric ton	0,01	t*km
W1a - Brick wall, cement mortar & plaster	**1**	**m²**
cement mortar, hand-mixed on site	80,08	kg
fired clay brick, clamp kiln	135,85	kg
cement plaster, hand-mixed on site	108	kg
W1b - Brick wall, cement mortar, clay/lime plaster	**1**	**m²**
cement mortar, hand-mixed on site	80,08	kg
fired clay brick, clamp kiln	135,85	kg
cement plaster, hand-mixed on site	108	kg
W1c - Brick wall, clay mortar, clay/lime plaster	**1**	**m²**
clay mortar	69,3	kg
fired clay brick, clamp kiln	135,85	kg
clay plaster	51	kg
lime plaster	51	kg
W2 - Unfired brick wall, clay mortar, clay/lime plaster	**1**	**m²**
clay mortar	69,3	kg
fired clay brick, clamp kiln	141,57	kg
clay plaster	51	kg
lime plaster	51	kg
W3 - Wattle-and-daub-Wall	**1**	**m²**
wood (unspecified timber)	0,01	m³
steel nails	0,01	kg
emuli (elephant grass)	1,84	kg
banana fiber	0,29	kg
clay mortar	132,00	kg
L1 - Concrete tie-beam	**1**	**m²**
concrete, hand-mixed on site	77,51	kg
reinforcing steel	1,85	kg
sawnwood, softwood, raw	0,03	m³
steel nails	0,08	kg
L2 - Wooden lintel	**1**	**m**
sawnwood, hardwood, raw	0,015	m³
steel nails	0,08	kg

tab.2 Input quantities (per functional unit) for the evaluation of building components.

C1a - Conventional Ceiling, cement plaster	**1**	**m²**
cement mortar, hand-mixed on site	62,4	kg
sawnwood, hardwood, raw	0,00516	m³
steel nails	0,04	kg
steel wire mesh	0,625	kg
C1b - Conventional Ceiling, clay plaster	**1**	**m²**
clay mortar, hand-mixed on site	54	kg
sawnwood, hardwood, raw	0,00516	m³
steel nails	0,04	kg
steel wire mesh	0,625	kg
C2 - Conventional Ceiling, clay plaster, papyrus ins.	**1**	**m²**
clay mortar, hand-mixed on site	54	kg
papyrus stalk	15,48	kg
sawnwood, hardwood, raw	0,00516	m³
steel nails	0,04	kg
steel wire mesh	0,625	kg
C3 - Papyrus / emuli ceiling with clay plaster	**1**	**m²**
clay mortar	54	kg
banana fibre	0,2	kg
emuli	0,603168	kg
papyrus stalks	15,48	kg
steel nails	0,02	kg
R1 - Metal Roof	**1**	**m²**
galvanized steel nails	0,028	kg
powder-coated steel sheet	1	m²
round timber	0,0205	kg
sawn timber	0,0045	kg
steel nails	0,016	kg
R2 - Thatched roof	**1**	**m²**
speargrass	19	kg
banana fiber	0,2	kg
emuli	0,4	kg
round timber	0,0205	kg
sawn timber	0,0045	kg
steel nails	0,016	kg
O1 - Steel doors	**1**	**m²**
hot rolling, steel	12,56	kg
metal working, average for steel product manuf.	7,85	kg
section bar rolling, steel	4,71	kg
steel, unalloyed	12,56	kg
transport, freight, lorry 3.5-7.5 metric ton	1,26	t*km
transport, freight, lorry 3.5-7.5 metric ton	0,13	t*km
welding, gas, steel	0,80	m
O2 - Steel Windows	**1**	**m²**
flat glass, uncoated	6,08	kg
hot rolling, steel	4,71	kg
section bar rolling, steel	4,71	kg
steel, unalloyed	4,71	kg
transport, freight, lorry 3.5-7.5 metric ton	1,08	t*km
transport, freight, lorry 3.5-7.5 metric ton	0,11	t*km
welding, gas, steel	1,20	m

Intermediate Products

Product / Input	Amount	Unit
Concrete	**1**	**kg**
cement, Portland	0,2733	kg
sand	0,4	kg
gravel	0,3377	kg
water, harvested from rainwater	0,168	kg
Cement Mortar/Plaster	**1**	**kg**
cement, Portland	0,2733	kg
sand	0,7377	kg
water, harvested from rainwater	0,168	kg
Lime Plaster	**1**	**kg**
lime, hydrated, packed	0,12	kg
sand	0,88	kg
water, harvested from rainwater	0,17	kg
Clay Mortar/Plaster	**1**	**kg**
clay, extracted from site	0,2733	kg
sand	0,7377	kg
water, harvested from rainwater	0,168	kg
Fired Clay Brick	**1**	**kg**
clay extraction from swampland	1,00	kg
heat production from wood incineration	4,76	MJ
water, unspecified natural origin, UG	0,12	m^3
Unfired Clay Brick	**1**	**kg**
clay extraction from swampland	1,00	kg
water, unspecified natural origin, UG	0,12	m^3

tab.3 Input quantities (per functional unit) for the evaluation of intermediate products.

LCA-Results for Building Components

Building Component		GWP	TA	OF	Ecotox.	Human tox.*
Roof Constructions [m²]						
R1	metal roof	24,63	0,06	0,05	67,43	30,29
R2	grass thatch	2,56	0,00	0,00	3,20	0,61
Ceiling Constructions [m²]						
C1a	conventional ceiling w. cement plaster	17,89	0,04	0,04	2138,98	2722,20
C1b	conventional ceiling w. clay plaster	2,91	0,01	0,01	900,41	1270,10
C2	conventional ceiling w. clay plaster & papyrus insulation	3,24	0,01	0,01	952,09	1331,59
C3	papyrus ceiling w. clay plaster	0,59	0,00	0,00	173,10	212,29
Wall Constructions [m²]						
W1a	brick wall w. cement mortar & plaster	61,61	0,14	0,38	164,69	46,22
W1b	brick wall w. cement mortar & clay plaster	40,80	0,10	0,33	142,85	37,58
W1c	brick wall w. clay mortar & plaster	21,00	0,06	0,28	116,56	30,55
W2	unfired brick wall w. clay mortar & plaster	1,49	0,00	0,01	7,49	0,94
W3	wattle-and-daub wall	1,71	0,01	0,01	6,99	1,19
Floor Constructions [m²]						
F1	concrete flooring	16,28	0,03	0,04	24,45	6,34
F2	rammed earth floor	1,53	0,03	0,01	6,68	1,86
F3	flagstone floor	5,23	0,03	0,01	10,31	2,99
Lintels / Tie-Beams [m]						
L1	concrete tie-beam	25,33	0,06	0,05	45,05	14,90
L2	wooden lintel	1,27	0,00	0,00	2,59	0,84
Doors / Windows [m²]						
O1	steel window	16,72	0,07	0,00	17,94	42,04
O2	steel door	43,10	0,11	0,10	62,19	121,68

* **GWP**..........Global Warming Potential [kg CO_2eq]
TA...........Terrestrial Acidification Potential [kg SO_2eq]
OF...........Ozone Formation Potential [kg NO_xeq]
Ecotox........Ecotoxicity [kg 1,4-DCB]
Human Tox....Human Toxicity [kg 1,4-DCB]

tab.4 LCA results for all building components.

stone used, as it makes up for the largest part of the material, and production techniques vary widely. Therefore, if no stone is available from resource-efficient quarrying in close proximity to the building site, it may actually compare unfavourably to cement floors. With a global warming potential of 1.53 kg CO_2eq, the sustainability of rammed earth floors is unmatched by any other construction, however, low acceptance of natural materials and the level of technical knowledge necessary to reach contemporary quality standards pose obstacles to their revaluation as a viable alternative to cement floors[21].

Windows and doors

No feasible alternatives exist for metal doors and windows for economic reasons as well as limited availability of both other resources like wood and skilled craftmanship related to these alternatives. Steel doors and windows have been included in the comparative LCA of the whole buildings, however results are not separately presented here. Together with foundations from fired brick, they constitute an invariable base factor for the environmental impact of any building. With 16.72 and 43.10 kg CO_2eq per square meter respectively, the global warming potential of both windows and doors is relatively high. Nevertheless, while brick foundations are responsible for a considerable percentage of the total environmental impact of the building, the impact of doors and windows is almost negligible due to the small share these openings have in the total area of the building envelope. Analogously, lintels and tie-beams necessary to bridge these openings have a negligible impact on the overall results of the whole building LCA, as their share on the total volume is even smaller.

Comparative Assessment

Fig.6 and tab.5 on the following pages show the results of the comparative LCA of the three building proxies. As mentioned above, foundations from fired brick and metal doors and windows constitute an invariable base factor for the environmental impact of all buildings. The conventional building (Proxy 1) has the largest ecological footprint, while the case study building (Proxy 2) already significantly reduces this input, ranging from a 13% reduction for terrestrial ozone formation to a 30% reduction for global warming potential. If the emissions reduction potential is used to full capacity, as for Proxy 3, the environmental impact can be further reduced to only 55% and 43% of the original building construction, respectively. In total numbers, this means that the global warming potential of the third proxy is reduced to only 10 049 kg CO_2eq as compared to 23 441 kg CO_2eq for the conventional building. As can be seen in fig.6, this means that as a consequence of the emissions reduction in all other components the invariable base amount from the building's foundations makes up for almost 72 percent of the global warming potential in the most sustainable construction.

Fig.6 also shows that, given their large share in the mass and volume of the whole building construction, the highest potential for reducing the environmental impact lies in alternative constructions for exterior and interior walls. By using unfired brick and wattle-and-daub walls instead of conventional wall constructions from fired brick and cement mortar and plaster, the global warming potential of the building can be reduced by 33%. Even if only the cement plaster is substituted by clay and lime plaster, this already means a reduction of the whole building's global warming potential by 17%. For the sake of completeness it should be added that the negligible environmental impact of lintels and tie-beams has been summarized under the results for walls, with the assumption that Proxy 1 uses a concrete tie-beam, while Proxy 3 uses wooden lintels, and Proxy 2 uses a combination of both, in the same ratio they were constructed on site according to the structural requirements of the real building on Bowa Hill.

The second highest potential for environmental impact reduction lies in the roof construction, where a 13% reduction in the global warming potential of the whole building can be achieved by exchanging a metal roof for a thatched roof. Both floor and ceiling construction have a smaller impact on the total environmental emissions reduction, however

fig.6 Comparison of LCA results for the three building proxies.

LCA-Results for the three Building Proxies

Environmental Impact / Component	Proxy 1	Proxy 2	Proxy 3
Global Warming Potential [kg CO_2eq]			
roof	3346,24	2280,72	369,72
ceiling	1120,57	37,44	37,44
interior walls	5715,71	3276,93	828,57
exterior walls	5091,07	3565,15	1277,15
floor	929,30	40,82	298,58
foundations	7218,86	7219,50	7218,47
doors/windows	19,31	19,31	19,31
Total	**23441,06**	**16402,44**	**10049,24**
Terrestrial Acidification [kg SO_2eq]			
roof	8,38	5,75	0,53
ceiling	2,16	0,15	0,15
interior walls	12,66	8,52	2,39
exterior walls	11,78	8,29	2,51
floor	1,74	0,09	0,69
foundations	18,42	18,42	18,42
doors/windows	1,20	1,20	1,20
Total	**50,13**	**36,52**	**25,50**
Ozone Formation [kg NO_xeq]			
roof	7,41	5,92	0,59
ceiling	2,55	0,19	0,19
interior walls	35,07	29,51	6,80
exterior walls	35,92	28,23	6,93
floor	2,15	0,04	0,82
foundations	66,62	66,62	66,62
doors/windows	1,02	1,02	1,02
Total	**150,74**	**131,33**	**82,96**
Ecotoxicity [kg 1,4-DCB]			
roof	9114,12	6677,73	446,31
ceiling	1864,07	180,72	180,72
interior walls	15274,09	12542,31	3879,43
exterior walls	15130,29	12381,28	4159,34
floor	1394,05	76,77	586,88
foundations	26568,69	26568,20	26567,02
doors/windows	947,69	947,69	947,69
Total	**70292,99**	**59798,12**	**36767,40**
Human Toxicity [kg 1,4-DCB]			
roof	4084,18	3503,08	80,80
ceiling	609,81	48,63	48,55
interior walls	4286,55	3438,70	850,96
exterior walls	4277,61	3322,97	814,78
floor	367,16	171,35	170,16
foundations	7606,17	7606,78	7606,43
doors/windows	444,01	444,01	444,01
Total	**21675,50**	**18535,52**	**10015,69**

tab.5 Numerical LCA results for the three building proxies.

a maximum reduction of the global warming potential by 2.7 or 3.7% is possible by replacing the concrete with a stone floor or a rammed earth floor, and a further reduction by 3.2% is possible by replacing the cement plaster in the ceiling with clay plaster, or 4.7% when the steel wire mesh is replaced by a plaster base from natural materials like papyrus, as used in the project.

(Inter-) National Context

To put the environmental impact into a broader context, the global warming potential of Proxy 2 is contrasted by the average global warming potential of the construction of a building of similar floor area in a Central European context in fig.7 below. Additionally, emissions for both the European context and the conventional Ugandan reference building are depicted as normalized per capita, based on statistics for the average size of available residential space in both countries. This contextualization shows that, while significant emission reductions in the Ugandan building sector are possible and should be pursued, when it comes to the environmental footprint of an individual's residential situation in Uganda, even the impact of the worst-case scenario modelled in the LCA does not even remotely draw near to that of an industrialized country in terms of its magnitude.

It is important to note that such comparison should not serve as an argument to diminish the efforts taken in the applied research towards environmental impact reduction but to make the results more tangible and add another perspective especially for Central European readers. Even though the methods and impact categories chosen for the evaluation of the building and its components do produce meaningful results, many issues

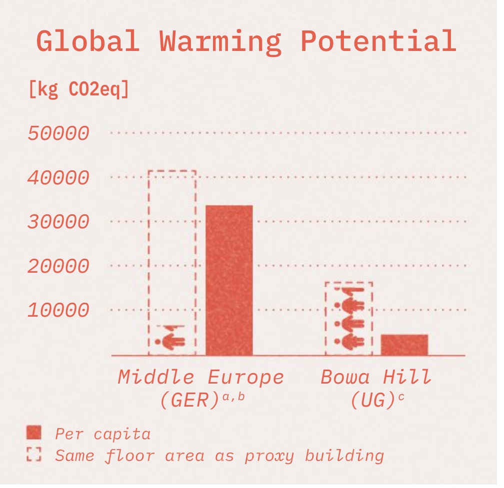


fig.7 International contextualization, weighted per capita.

related to the environmental impact of building constructions in Uganda can not be adequately represented in the LCA results presented above. With one of the fastest-growing populations in the world, extensive land-use by small-scale residential construction is not limited to the sprawling metropolitan areas but is a growing issue in rural regions as well. As many resources for the production of semi-industrialized building materials are sourced directly from the immediate environment, building construction is linked to the ever more pressing issue of deforestation and environmental degradation, especially in the production of fired bricks in small wood-fired scove kilns, as shown in the first part of this thesis. For this reason alone, implementing different practices in contemporary non-engineered building construction seems almost imperative.

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ad **fig. 14** Calculations by the authors based on the following sources:

a Umweltbundesamt (Hg.), Mahler, B. et al. (2019) *Energieaufwand für Gebäudekonzepte im gesamten Lebenszyklus. Abschlussbericht*, p.49. Dessau-Roßlau: UBA.

b Statistisches Bundesamt (2023) *Wohnungsbestand im Zeitvergleich* [online]. https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Wohnen/Tabellen/liste-wohnungsbestand.html (Accessed: 10 December 2023).

c Uganda Bureau of Statistics (2021) *Uganda National Household Survey 2019/2020*, p.62. Kampala: UBOS.

On Transformation Prospects and Limitations

Benedikt Mass / Maximilian Weidacher

With the final chapter we return to Bowa Hill and our initial question of how we, as architects or engineers, can contribute to the transformation of contemporary vernacular architecture. In an attempt to relate the findings of the construction process to the multitude of often conflicting factors that have emerged from our research, we hope to highlight both the potentials for transformation as well as the limits of feasibility. Following the structure of previous chapters, we have summarised our considerations for each component separately. General thoughts and prospects are discussed in the last paragraphs.

By Building Component

A pervasive method throughout the study is the decomposition of buildings into aggregates of interrelated components. In essence, this fragmentation served to structure investigations and facilitate comparison. However, given the limited sphere of influence of architects and engineers in the context of a building culture characterised by anonymous architecture, thinking of a building as a sum of individual components can also be seen as a strategy that allows for an incremental, situation-specific transformation. In the case of the Central Region of Uganda, the approach seems particularly relevant as the contemporary vernacular typology is already based on the customary concept of increments of an ideal home. While the construction kit presented in the previous chapter was initially used to assess environmental impact, it is also a first step towards the expansion of the existing architectural vocabulary, reconciling renewable resources with semi-industrialised and industrialised building materials.

Floor

While a large majority of 69% of Uganda's population live in houses with earthen floors, especially in rural areas[1], earthen floors are usually seen as an intermediary solution to be replaced by "proper" flooring. Such a floor, as shown in the chapter on common practice is a concrete screed, possibly finished with cement slurry or floor tiles, depending on the owner's budget. Conceived as only temporary, the quality of earthen floors is mostly poor, even if a concrete floor will never be built. As the status value is low, traditional skills and material knowledge are being lost, consolidating the prevailing image. As noted in the construction diary, we came to realize, that it would take further effort and research to construct earthen floors under the given circumstances. In addition to the challenging composition of the soil, the sample patch of rammed earth floor proved not to be termite safe, as the insects burrowed through it after several weeks.

As Robert watches us working on our meticulously prepared sample patches of rammed earth floor, he tells us with an amused glint in his eyes how earthen floors are usually made. Actually today such floors are rather a side product of the cleaning processes at the end of construction. As heaps of broken bricks, lumps of mortar, bent nails, pieces of metal wire and the occasional broken shoe or empty bag of cassava flour have accumulated around the construction site, porters shovel all the debris into the house from all sides through door and window openings, finally covering the mess with a layer of clean soil, excavated from where the brick foundations now sit. Once the cleanup is completed, a hand full of "stompers", unskilled labourers from the area, literally stomp down the floor with their bare feet and bodyweight in exchange for a hot meal and a few shillings.

Further literature research showed that termite resistance can be achieved by using a physical termite barrier made from coarse sand that prevent termites from tunneling through. While the grain size of these barriers varies depending on the termite species, a narrow safe range of between 1.7 to 2.0 mm of effective grain size exists for all termite species. To be effective, particle barriers require proper installation and must not be contaminated by soil or particles from different grain sizes.[2] Given the complexity involved, it is questionable whether such measures can be implemented on a larger scale for countries like Uganda.

As a rough estimate, during transport and construction, almost 10% of bricks are damaged beyond usability, providing an ample source for secondary resources. In a second floor sample, we picked up the idea of recycling construction waste and tried to reduce the environmental impact by replacing quarried gravel with brick residue. When crushed to even smaller pieces, they can be used to produce a terrazzo-like screed, both in combination with cement and lime as a cohesive material.

Where there is an abundance of flat, slate-like rock, as in the case of Bowa Hill, a floor of stones in a sand bed with cement-lime grout appears to be a viable alternative. The more careful the irregular stones are laid, the less grout is needed. If however, suitable stones are not available locally, processing factors such as quarrying, cutting and transport must be considered in terms of costs and environmental impact. In such cases the second floor type from recycled brick waste may be the preferred over the common cement screed.

Wall Construction (Brick)

Most residential buildings we saw on our field trip were made from industrialised or semi-industrialised materials. Housing surveys on a national level however show that only approximately 56% of Ugandans live in houses made from fired brick,[3] while the remaining half live in earthen homes. In favour of further research into the contemporary vernacular typology and against our initial impulse, we decided to settle on a conventional brick construction.

At the construction site, we learn that there are two types of brick: clay bricks and mud bricks. Clay bricks are made by migrant craftsmen in temporary manufacturing sites, which are usually located near swampy areas. The dark, alluvial clay is mixed with water in large pits and then shaped by hand into bricks in wooden moulds. After drying thoroughly in the sun the bricks are fired in large, mud-packed scove kilns. When a deposit is exhausted, workers move on to the next site. Sold by subsistence farmers in small quantities as an additional source of income, mud bricks are much cheaper than clay bricks. But they are also mostly of poor quality, as they are produced from almost any locally available loamy soil. Having grown up in the countryside, Lawrence knows much about the brick side-business. He tells us that the production process is much the same as for clay bricks, only the kilns are smaller. Taking advantage of the cool nights, firing usually begins in the late afternoon and ends in the early hours of the morning when the chamber is closed with mud. The glowing embers may continue smouldering throughout the next day, and the kilns can take a week to cool down. As a kiln cools from the outside to the inside, the bricks in the centre are of a higher quality and therefore sell for a higher price. Lawrence says that it gets increasingly difficult to fire large quantities of bricks as firewood becomes scarcer.

As with most parts of a building, the choice of brick depends primarily on the homeowner's budget. In comparison, clay bricks cost up the 300 shillings per piece, while mud bricks usually sell for 120 shillings. For the construction of the case study houses, we decided to incorporate both clay and mud bricks, depending on the function or the intended use. Since the foundations are exposed to high levels of moisture, we felt it made sense to use the higher quality clay bricks. For the walls, on the other hand, the overall quality of mud bricks seemed sufficient. Our main observation on site was that the easiest way to create stronger bonds, while at the same time reducing the necessary amount of cement mortar, would be a different brick format.[4] On our first day we already observed that, apart from a running bond, no other conventional brick bonds can be laid, as the brick format does not take the width of the joints into account. Masons have two ways to compensate for the flaw: either by perpend joints of excess width or by trimming bricks at regular intervals. At corners or wall intersections, the problem is most pronounced, thus weakening the whole structure. As both clay and mudbricks are made under similar conditions, the brick size could easily be adjusted by using a brick mould with a different side ratio. The naturally irregular shape of the manufactured bricks adds to the excessive mortar use and the overall structural instability of the brickwork. Unlike the brick format, the irregular shape is the result of local production processes, which in turn are part of a national – albeit informal – economy and cannot be easily counteracted.

For the case study buildings, the first potential in reducing considerable amounts of cement used we saw in replacing the continuous tie-beams with wooden lintels where possible. As described in the construction diary, such seemingly minor deviations from the norm already led to long discussions with Robert, our builder, and the workers. Our attempts at structural reinforcement through segmentation with stronger inner walls and folding of the masonry seemed to have a positive effect on the overall integrity, however the measures did not suffice to replace all reinforced concrete beams. Considering the poor structural integrity of the walls we would also recommend that the walls are punctuated as little as possible, with enough spacing between the openings. Mortising holes for the temporary fixing of scaffolding means an additional perforation of the walls, further weakening the load-bearing structure. Anticipating regularly spaced perforations during brickwork would not only protect the walls, but also save labour.

We have tried to further reduce or rather avoid the use of cement in all non-structural applications that are not exposed to rain. The gable walls were made from wattle and daub, and clay mortar was used for stud walls. The modification of local soil by adding unwashed sand (and additional sieving in the case of mortar) has produced stable, workable building materials. Structurally, and in terms of feasibility, all three wall experiments (the wooden lintels, the gable and the knee walls) proved to be relevant alternatives. Initially we also considered constructing parts of the buildings with unfired brick but decided against it for the time being. While it is possible to obtain unfired bricks from local producers, they are not suitable for transport along bumpy Ugandan roads. As they are intended for being burnt in local scove kilns, they do not contain fibrous additives as a reinforcement, making them fragile in their unfired state. Due to the short period intended for building construction, local production on site was not an option, even though, in principle, possible.

Wall Construction (Wattle and Daub)

Our attempts to build earthen walls are limited to the non-load-bearing gable walls. An interesting discovery during our material experiments were Lawrence's specific skills, that appear to be traces or remainants of what we have called the transient vernacular typology in our research. Although the typology probably had some novelty value compared to the Kiganda at the time of its emergence, wattle and daub structures are now generally regarded as inferior. Among other aspects, this is reflected in the fact that renewable resources are mainly used for outbuildings such as kitchens, storage spaces or stables. In the way wattle and daub buildings are made today, we see a confirmation of our hypothesis, that the construction method is not the product of a slowly evolving, elaborate craft tradition, but rather a spontaneous intermediate state. As more and more people live in


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houses made of industrialised and semi-industrialised materials, there has been no visible transformation or evolution in this transient vernacular typology. Presumably conceived as a temporary compromise from the outset, the few earthen buildings we saw shared the same structural flaws.

One of the main problems with local earth buildings is moisture or the lack of protection against it. Similar to the Kiganda, the structural poles are driven directly into the ground, but are usually made of wood species that are not rot resistant and are rarely treated against termites or fungi. Moisture in the ground causes the poles to rot, reducing the lifespan of the structure. The walls also sit directly on the ground, further weakening the structure through rising moisture. Another risk to earthen walls are the heavy tropical rains. Often the substructure is exposed on one or more sides due to erosion of the clay material.

Unlike the beehive-shaped Kiganda, the transient typology is based on a cubic geometry that is much more susceptible to torsion and shear. The common image of buildings leaning in one direction indicates a lack of diagonal bracing or other means of reinforcement. If not maintained, the clay infill gradually loses its stabilising effect, causing structural damage that is often difficult to repair. It seems likely that the low monetary value of earthen buildings may contribute to the acceptance of deterioration to the point of structural collapse.

Wall Plaster

As with flooring, both cement and clay plasters are found in the immediate project region. Interestingly, it seems that fired brick buildings are almost never plastered with clay plaster, and since cement is expensive, they are usually left raw.

Our field experiments and the subsequent soil analyses conducted at the University of Natural Resources and Life Sciences Vienna (BOKU) showed that earthen plasters can be produced with most soils but require the addition of both mineral and fibrous aggregate. In the case study houses, the addition of sand combined with coarse sawdust proved to be effective. Based on our observations, such tempering (to prevent cracking and increase cohesion) does not appear to be a common measure or known practice. Replacing cement with lime would be another, more intermediate step towards emission reduction. However, from a practical standpoint, the necessity for dry storage (in the case of tropical climates in air-conditioned spaces or else with airtight packaging) and the low demand significantly reduce the potential of lime as an alternative to cement.

During the building workshop we noticed that our peculiar material experiments caught the workers' interest and triggered discussions. The initial fascination with our methodological approach was soon replaced by general confusion as to why we were experimenting with renewable resources, or poor materials as they would call them. Especially as there were already common solutions using valuable industrialised materials. In an interesting conversation about our aim to reintroduce renewable resources into common practices, Robert told us, that professionals in Uganda would not work with poor materials. In his opinion it was not a question of warranty, but of professional honor.

The first rainy season brought us two realisations regarding the exterior plaster. Firstly, we can see from the discolouration of the walls that rainwater splashes up to about 60cm from the ground. In order to prevent capillary moisture from rising through the external plaster and into the walls, a plaster of cement, lime or stabilised clay should be used. Secondly, after only one of two annual rainy seasons, the exterior plaster samples from clay were noticeably washed out. If the entire façade were to be rendered with clay plaster, it is likely that the surface would have to be reworked at least once a year. To reduce maintenance work, particularly exposed areas could be additionally protected by planting vegetation at a safe distance from the façade. It is important to note, that any type of exterior plaster provides a protective wearing surface for the already fragile masonry. In this sense, plastered façades increase the longevity of a building.

Ceiling

While the thermal assessments in the pre-design phase have shown that the ceiling and roof construction have the greatest influence on the prevention of overheating, in contemporary vernacular buildings, the primary function of the ceiling is to provide a spatial separation between the living space and the usually unused attic. Like the interior and exterior plaster, the ceiling is also considered optional, i.e., if the budget allows it, a ceiling is built, and if not, the component is omitted. To our knowledge, ceilings are always made from cement plaster applied to a wooden lattice, as described in the construction diary. Although our attempts to produce a conventional ceiling construction using clay plaster were quite successful, we are not aware of any such practice in the project region. A clay ceiling is already a cost-effective and resource-efficient alternative to conventional ceiling construction. The inclusion of fibres would further increase the insulating properties.

When experimenting with natural materials to improve the thermal performance of ceiling constructions, papyrus stalks proved to be very promising. Dried papyrus stalks have excellent thermal properties, making them ideal for use as a natural insulation material.[5] The fibrous stalks almost feel like a sponge or polystyrene foam, yet they are surprisingly strong and pressure robust. The stalks can be up to 4 meters tall and up to 5 cm in diameter, with an almost triangular cross-section that makes it easy to lay them across ceiling joists. Single-layered papyrus mats are produced locally throughout the Central Region and are often used as cheap wall coverings or for shading. Instead of tying thicker, multi-layered mats, as we did for the ceiling sample, the two houses' ceilings were made of loosely piled papyrus, with no protective layer of plaster on the top. Nevertheless, no insect or vermin infestation has been observed to date. Although the papyrus ceiling has the highest insulation value of the alternative ceiling constructions assessed, fire resistance needs to be addressed before it can be recommended for general use, as a large part of the population cooks on open fires.

As we attempted to translate the Kiganda reed ceiling into a contemporary application, we realised the effort and patience that such construction requires. Compared to papyrus, emuli is more robust and therefore less susceptible to infestation, but its higher density makes it less insulating. On the positive side, it is also less flammable. Both reed and papyrus grow abundantly in the countless swamps of Uganda's central region and are renewable resources that have the potential to be used on a large scale.

Roof

The roofers' work was characterised by efficiency and speed; there seems to be little room for optimisation. We noticed two things about the first element, the bottoms, which are the connection between the masonry and the roof truss. As with the scaffolding, the mortising of holes in the brick walls, through which the bottoms (wall plates) are attached, represents a severe weakening of the supporting structure in some places. Dedicated lashing slots could be provided or existing scaffolding recesses reused. Secondly, if the individual wall plate slats were not only fastened to the walls but also properly joined to one another and the corners braced, their contribution to the structural integrity of building would be significantly enhanced.

In terms of construction and stability of the roof itself, we feel that the pseudo-hipped roof we proposed for the buildings on Bowa Hill is a good alternative to both a conventional pitched roof as well as a hipped roof. The steep hipped surfaces are particularly suitable for thatching with grass, as the water can run off quickly. The buildings did not overheat even on the hottest days, suggesting that the shading of the gable walls was effective and that the cross-ventilation of the roof space was sufficient. Lisa and David noticed that after a short time, bats began to colonise the space between the thatch and the gable wall, becoming the guardians of the attic. The tight mesh over the vents in the gable wall seems to have successfully prevented the bats and other larger animals from inhabiting the roof space.

Given that the majority of roofs in the Central Region are covered with corrugated steel sheets, the results of the experiments with traditional thatch are particularly valuable to us. Once we had worked out the construction details with David and his uncles, the grass roofs were easy to install. With the background knowledge from our preliminary research into lost practices, our only concern was that the bundles would disintegrate over time as the grass was processed immediately after harvesting and not dried beforehand. To our surprise, it turned out that it was not the fresh grass that was the problem, but rather the choice of cord we used, as after a few months, all the bundles exposed to the sun came loose. Apparently the cord was not UV resistant. Mostly it was the trim-bundles that were affected, a detail we hadn't resolved, and the damage was easily repaired. As with emuli and papyrus, essubi (spear grass) was easy to obtain and cheap once transport was arranged.

From a financial point of view, thatch is an economical alternative to metal roofing, especially when done by the homeowner or local labourers. However, the low status value of the material, the maintenance requirements, and the unsolved fire safety issues should not be ignored.

Feasibility Constrains

To conclude our final evaluation of the applied research, we want to return to our initial question of the possibilities of transformation, in contrast to our observations on feasibility constrains and the limits of our influence. The results of the life cycle assessment[6] of Proxy 3, the improved building, show that an intensive use of renewable resources directly translates to a radical reduction of emissions. However, from a practical standpoint, the level of impact reduction also implies a change in construction method. In the necessary transition from the traditional brick and mortar structure to a tectonic timber structure, we see three major challenges.

(1) Our description of wattle and daub buildings in the Central Region suggests that a collective understanding of the transient vernacular typology still exists. Since the local earthen buildings have a number of serious constructive flaws, fundamental structural modifications would be required to meet today's standards of safety, durability, and comfort. Compared to replacing individual components, changing from one structural system to another is a significantly larger intervention. (2) Like its predecessor, the Kiganda, the bearing structure of the transient vernacular typology is made of wood. Given the increasing deforestation in Uganda, propagating a typology that relies on a scarce resource seems problematic. Although bamboo, as discussed in the research, would be a suitable, fast-growing substitute for wood, increased use of bamboo[7] would also require a sustainably managed industry. (3) The lack of integrity of owner-built wattle and daub structures, as well as professionally constructed roof trusses, indicate that local woodwork is characterized by simplicity and efficiency rather than intricate elaboration. Whether made of wood or bamboo, the state of current skill sets must be reflected in a typological change.

Craft and Value Systems

While the measures taken in the case study buildings proved to be already effective in terms of both improving thermal comfort and reducing environmental impact[8], it also became apparent that the recognition of craft skills, practices and customs is relevant at a seemingly low level of transformation. After all, the greatest challenge was to find people who were not only able, but also willing to work outside the confines of common practice, demonstrating that transformation is not only a question of practical but also of cultural feasibility.

In the chapter on common practice, we posed the hypohesis that while the non-engineered or anonymous architecture of the Central Region remains embedded within a customary one-typology framework, the introduction of industrial materials induced a diversification of formal expression.[9] In turn, the expansion of

expression goes hand in hand with an increasing importance of the status value of buildings and the materials of which they are composed. From a socio-cultural perspective, architecture and vernacular architecture in particular, gives expression to an underlying value system that per se cannot be dealt with from within, i.e. by architecture alone. Given the limited sphere of influence of architects, integration into existing cultural patterns based on an understanding of the underlying value system appears to be an appropriate approach.

When comparing the status value of renewable building materials with that of semi-industrialised and industrialised building products, the question arises as to what distinguishes one from the other and what factors influence the scale of values. The first essential difference is that semi-industrialised and industrialised building products have undergone some form of processing, whereas renewable building materials usually arrive on site as raw materials. Labour intensive pre-processing is shifted into the construction process, resulting in inconsistent quality and a general slowdown in workflow. A further distinction relates to attributed material properties, with building materials made from renewable resources generally perceived as less durable than industrialised building products. Objectively, however, this argument is only partially valid, as durability is primarily a consequence of use and application, and depends to a large extent on care and maintenance. Lastly, compared to building products, building materials purchased as raw resources have little, if any, monetary value, which directly affects their status level.

Semi-Industrialised Prospects

Returning to the idea of integration into existing patterns, the example of the manufactured brick illustrates a curious phenomenon that may be translated to other natural resources. Produced in a semi-industrialised process, this essentially crude building product is commonly understood as a symbol of prosperity and progress.

In the same way, renewable building products such as insulating panels made of papyrus, roofing elements made of thatch or refined clay plasters could be manufactured. As with clay bricks, decentralised production units would provide missing employment opportunities in rural areas. Diversifying small-scale home production of building materials could generate additional income for the growing number of families who can no longer survive on subsistence farming alone. From the perspective of builders and craftsmen, pre-processing and prefabrication can ensure consistency of quality and accelerate workflow. Increased use would inevitably be accompanied by a professionalisation of application and ehanced quality standards.

As a secondary benefit, the processing and partial commodification of renewable building materials could have a positive impact on their low status value, thus leading to a transformation of collective building practices.

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A	Research	Geography, East Africa and the Great African Rift
		Climate, Within the Intertropical Convergence Zone
		Vegetation, The Tragedy of the Commons
B	Planning	Pre-Design, Typology and Thermal Comfort
D	Evaluation	Life Cycle Assessment, Qualitative Evaluation

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A	Research	People, Cultural Diversity and the Baganda
		City and Countryside, The Rural-Urban Divide
		On Buildings, Three Kinds of Vernacular
		Lost Practice, The Historic Vernacular
		Common Practice, The Contemporary Vernacular
C	Construction	Construction Diary, Learning From Bowa Hill

The following chapters were written collaboratively by the two authors.

/	Preface	Abstract
		Introduction
B	Planning	Design, Plans for Bowa Hill
D	Evaluation	Building Materials, Index and Analysis
		On Transformation, Limitations and Prospects