Small Scale Photographs and Land Resources in Nyamweziland, East Africa

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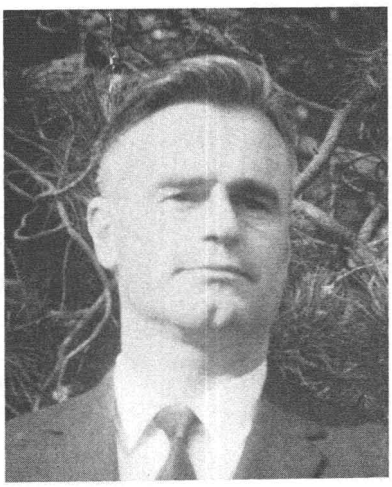
ABSTRACT: *Up to the present time, very little has been published concerning the photo interpretation of areas of tropical woodlands as distinct from tropical closed forests. The writer shows how the woodland formation can be divided into nine main forest types and ten land types for agricultural purposes. In addition suggestions are put forward concerning grazing, big game protection and the control of endemic disease.*

1. INTRODUCTION

THE area covered in this discussion is the home of the Nyamwezi people in Western Province, Tanganyika. Nyamweziland occupies about 42,000 square miles in a province of 72,000 square miles (Figure 1). Most of the land lies between 3,800 ft. and 4,500 ft. above sea level; and comprises a gentle undulating peneplain with granitic extrusions of 50 ft. to 200 ft. In the northeast, this gives way to lacustrian deposits, parts of which are annually flooded. Rainfall, confined to about 6 months of each year, is between 30 and 40 inches, but somewhat less in the east and northeast. Rivers are few and usually seasonal. The mean annual minimum temperature is 60° to 65°F., and the mean annual maximum temperature is 80° to 85°F. Most of the Nyamwezi people live in the northeast and near the principal town, Tabora. The remaining areas are sparsely inhabited. Tropical woodland,* mostly unhabited, covers up to 80% of Nyamweziland. The woodland formation extends from Lake Victoria southward for nearly 1,500 miles into Southern Rhodesia. The equivalent of the woodland formation occurs in tropical South America, northern Australia and southeast Asia. In eastern Nyamweziland, the woodland gives way to thicket and in the northeast to grassland.

2. THE AERIAL PHOTOGRAPHS

Most of Nyamweziland has been covered by aerial photographs. The scale of the photographs is small for interpretation, as 1/30,000 photographs were primarily required by the Government for photogrammetric mapping, and the remainder were flown by a private company at 1/20,000 for geological survey. Part of the area was covered by photographs at both scales, but after some practice at local interpretation, it was found that there was little additional information to be obtained from the 1/20,000 photographs. The ensuing remarks relate to 1/30,000 vertical photographs. Side-lap was usually 15% to 20%, and end lap was 55% to 65%.



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Most of the flying was undertaken between June and September. Prior to June the cloud cover is usually heavy or at least so unpredictable as to make flying for aerial photographs uncertain. After early September, and until the rainy season begins in November or

* Important synonyms are: savanna woodland, miombo woodland, dry deciduous woodland, Isoberlinia-Brachystegia savanna (Burtt), dry forest (Shantz), open woodland and savannewald (Schimper).

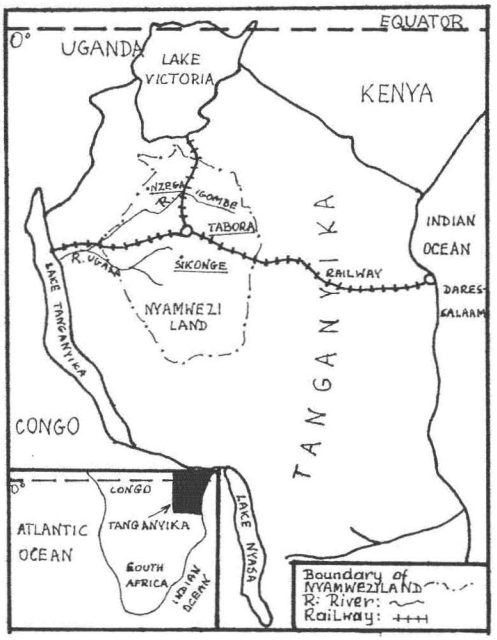

FIG. 1. Nyamweziland occupies about 42,000 square miles of the largest province of Tanganyika and is situated between 3° and 6° south of the Equator.

December, haze produced by extensive, annual forest fires becomes so dense that much definition is lost in the photographs. The forest fires do little damage to the larger trees, being confined to the grasses and other herbs. The aircraft usually flies at 15,000 feet above ground level. Good resolution and probably the best edge gradient were obtained on photographs flown in June and July. Usually a 6-inch Ross wide angle lens was used in combination with Williamson MBV 2 vignetted filter. This filter is equivalent to a Wratten No. 8. The film was usually Ilford Hyperpan. "ID" developer was used and printing made on double weight paper with a glossy dried matte finish. A full matte finish would have been preferred for field work as it is more easily marked with a chinagraph pencil, but the glossy finish provided a photograph more resistant to rough handling by field staff.

3. LAND USE

Land as a factor of production is only partly used in Nyamweziland, and where it is fully used management is extensive. Only in the northeast, near Tabora, and in the vicinity of the larger settlements, the land has acquired a scarcity value. In these areas potential productivity is often limited by diminishing supplies of water, capital and "enterprise"; and elsewhere potential productivity is limited by the scarcity of labor. In the vicinity of the larger settlements, resource use favors agriculture due to the increasing returns to scale. Throughout most of the woodland, the tsetse fly is the limiting factor to increased ranching.

In relation to land resource use, the aerial photographs fulfill at least three important functions. For forestry the photographs provide information useful in programming timber cruises and also help in choosing areas most suitable for permanent forest reserves. Under prevailing conditions, saw-milling and the beeswax industry are the only two economic enterprises for vast areas of the tropical woodland formation. Secondly, the aerial photographs provide information useful in choosing areas suitable for new agricultural settlements and for maximizing production in these areas. Finally, the photographs provide information on existing management of settled areas and indicate adjustments that should be made in the balance between forestry, agriculture and range management. Ranching is confined mainly to the north and northeast. Recently tobacco farming has developed to the west of Tabora; and aerial photographs may help in assessing the acreage of available tobacco soil and soils best suited to the growing of ground-nuts.

The term woodland is applied to the forest lands to distinguish them from the tropical tall closed forest occurring in areas of higher rainfall to the northwest and west of Nyamweziland. It is doubtful if there is any true tropical rain forest in Tanganyika.[9] The term miombo woodland is considered to be inappropriate as miombo is the Kinyamwezi name for one tree species (i.e. *Brachystegia boehemii*) which, although a common species, is rarely a dominant species.

4. INTERPRETATION FOR FORESTRY

Within the woodland formation nine important ecological main types were recognizable on the photographs. These were distinguished by differences in tone, crown closure (texture) and sometimes shadow; and in stereovision by apparent differences in the stand height of the mature trees from regeneration, thicket and shrubs. The Itigi thicket, an ecological formation to the east of Nyamweziland, was usually recognizable on photographs by its finer texture and uniform height of 15 to 25 feet.

TABLE 1

KEY OF PRINCIPAL ECOLOGICAL TYPES OF WOODLAND FORMATION

(Based on crown closure of the trees and potential saw log value.)

Hilltop

1. Woodland—50% of the ground covered by the crowns of medium and large trees
   a. HILLTOP WOODLAND (*H/W*); e.g., *Brachystegia tamarinoides* woodland
   b. BRACHYSTEGIA-JULBERNARDIA woodland (*BJ/W*). Mainly *B. spiciformis* and *J. globiflora*.

Herb line *H/L*

   c. VALLEY WOODLAND (*V/W*): often as islands in the wooded grassland, e.g., *B. bohemii*
2. Wooded grassland—under 50% of the ground covered by the crowns of large and medium size trees
   d. WOODED GRASSLAND *with* WHITE-ANT HILLS (*W/GT*).
   e. WOODED GRASSLAND *without* WHITE-ANT HILLS (*W/G*).
3. Grassland—large and medium size trees rare or absent.
   f. GRASSLAND WITH BUSHES AND DWARF TREES, e.g., Acacia and Combretum species (*AC/G*).
   g. PALMSTAND GRASSLAND, e.g., *Borassus flabellifer* on abandoned village sites.
4. RIVERINE (*R*)—usually riverine woodland or riverine thicket. Occasionally closed forest species up to 100 feet high.

Valley Bottom

5. Other main types.
   i. REGENERATION THICKET (*R/T*)
   j. INDUCED CULTIVATION by man.
   k. PERMANENT SWAMP—considered absent.

The key (Table 1) was prepared after examining photographs covering 1,500 square miles of the woodland formation, and gives the principal ecological types in catena sequence (Figure 2) from hill-top to valley bottom.[8] Soil types are considered to conform fairly closely to the eco-types, and therefore a similar classification has been used for soils in Section 5. The herb-line, however, so conspicuous on aerial photographs of the woodland, as a thin whitish line, is difficult or impossible to locate on photographs of settled areas when the tree crop has been removed and the soil has been cultivated. On the ground the "herb line" is ideally an inconspicuous narrow ecological zone of herbs or grasses between woodland and wooded grassland; and sometimes is very difficult to locate without the aid of photographs. It may also be conspicuous on the photographs by the earlier burn in the dry season of the woodland grasses and by the abrupt termination of woodland where it adjoins *Acacia-Combretum* grassland. The term *line* and not *zone* is used as it is of greater importance to aerial photography than in ecology; and also to distinguish it from the ecological interzone.[4] As far as is known, the first text reference of the herb line was recorded in 1959.[8]

Usually, it was not possible to identify the species of a tree from the 1/30,000 photographs. Species recognizable, near Tabora, included *Brachystegia tamarinoides* on hilltops, due to its location and grayish tone; *Acacia pseudofistula* on grassland due to its location, very small grayish crown and distinctive shadow; *Borassus flabellifer*, a palm, by its characteristic crown and shadow, *Mangifera indica* (mango) on abandoned village sites by its very dark toned large dome-like crown and *Acacia rovumae* by its smaller flattish dark crown and location on the conspicuous termitaria. Two species may be co-dominant, ten species may be common and

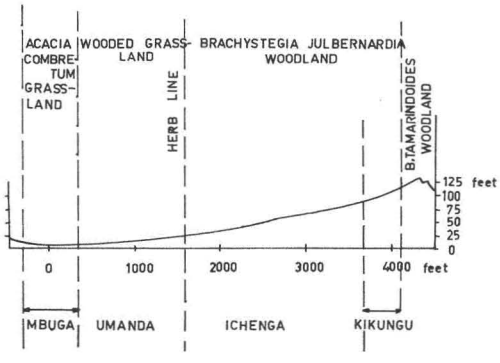

FIG. 2. Catena diagram showing the sequence of the principal soil types and the associated ecological types from valley bottom (mbuga) to hilltop (kikungu). This type of diagram is useful to the photointerpreter when he is type-mapping.

over forty species sparse to rare. As compared with (tropical) rain forest, the ground or herb layer is usually seen in the photograph, the crowns of the trees are not thickly interlaced and there is usually only one crown layer. In some respects the woodland formation resembles the hardwood forests of temperate Europe and America. In the *Julbernardia-Brachystegia* woodland, *Brachystegia spiciformis* recorded grayish black compared with its co-dominant *Julbernardia globiflora* light gray tone. *Pterocarpus angolensis* in tone was similar to Julbernardia; but lost its leaves in the dry season from 4 to 6 weeks earlier.

In Table 2, the percentage of the main ecological types are shown for 220 square miles of woodland near Sikonge, Tabora. For comparison, the percentage obtained from timber cruising are compared with those obtained from aerial photographs.[8]

From a resource use point of view, forest productivity is considered to be confined to the *Brachystegia-Julbernardia* woodland main type, and this represents about 50% of the total land area. This main type contains the saw log muninga trees (*Pterocarpus angolensis*). Muninga provides up to 100% of the output of the bush sawmills. In one area (Kigwa), it was observed that by delineating separately on the photographs areas of mature woodland with the highest *crown width/stand height* ratio, it was possible to locate areas with a muninga stocking four times greater than the mean stocking. The wooded grassland and the *Acacia-Combretum* grassland combined represent about a third of the total land area, and although unproductive for indigenous forestry, it is potentially valuable for agriculture, including possibly the growing of eucalypts for firewood.

At Kagua near Tabora, aerial photographs were used to site a sawmill in relation to saw log supply, water supply and all-year logging routes. The photographs showed that Kagua was surrounded on three sides by mature *Brachystegia-Julbernardia* woodland considered to contain saw log muninga and that suitable logging routes could be aligned to follow the well-drained eluvial soil above the herb line. Except in periods of prolonged heavy rain, the eluvial soils are passable to motor vehicles. In comparison, the grassland soils may be water-logged and impassable for a few weeks up to three months in a year. These could also be recognized and delineated on the photographs.

TABLE 2

PERCENTAGE OF MAIN ECOLOGICAL TYPES

Type	*Timber cruising* %	*Aerial photographs* %
Hill top woodland	8	6
Brachystegia-Julbernardia woodland	48	50
Wooded grassland	24	27
Acacia-Combretum grassland	10	9
Regeneration/Thicket	10	8
Total (220 square miles)	100	100

5. INTERPRETATION FOR AGRICULTURE

The aerial photographs serve at least two important functions. In uninhabited or sparsely populated areas of woodland, the photographs enable a choice to be made quicker and more efficiently of sites for new settlements. The new village can be chosen best to satisfy communications, soil requirements, water supply and health.

Secondly, the boundaries of principal soil types can often be delineated. This provides an assessment by area of the soil types and helps in deciding the crops to be grown. In a woodland area for new settlement, the delineation of the soil types on stereo-pairs of photographs follows closely the boundaries of the main ecological types outlined in Section 4, but it is necessary to separate the *Brachystegia-Julbernardia* main type into two sub-types to conform to the soil types locally termed "kikungu" and "ichenga". Usually, the two soil sub-types can be separated by differences in the time of leaf-fall and leaf-flush, by differences in the apparent stand height of the trees and occasionally by crown closure. On "kikungu" soils, near Sikonge, the stand height was frequently five to ten feet greater than on "ichenga".

On land already settled it was more difficult to delineate the boundaries of the soil types on the photographs, especially as the herb line is absent. The principal soil types have been delineated on the photograph (Figure 3). This photograph covers a peasant farming area about three miles north of Tabora. The sequence of soil types is also shown in the catena diagram (Figure 2). Catena diagrams are a useful aid to the interpreter when delineating tropical areas for agriculture, forestry and land use. This is partly due to the close association existing between forest type and soil type in extensive areas of the tropics.

The main soil types of settled areas, identifiable on the photographs in conjunction with ground checking are as follows. These

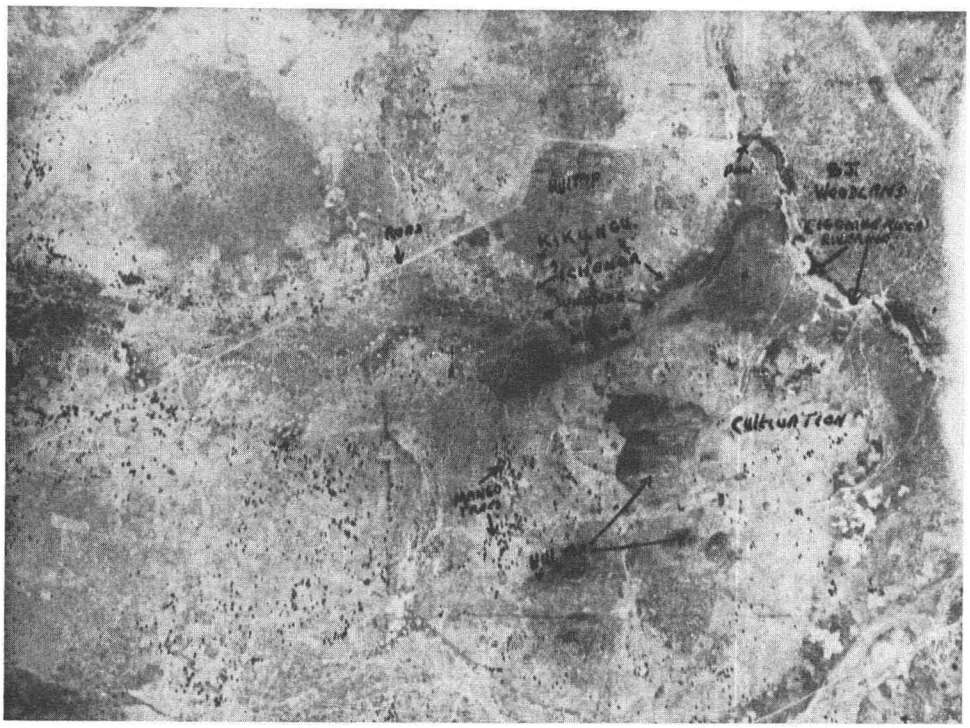

FIG. 3. Area of recent settlement near Tabora. Four soil types and three woodland types are shown. Note also the conspicuous mango trees, the road, termitaria to the northwest of the road and the pools along the river.

have been arranged in the catena sequence of Figure 2.

1. HILL TOP SOIL in the vicinity of porphyllitic granitic gneiss outcrops and ironstone ridges. The soil is usually too shallow for general agriculture. The presence of rock outcrops in the form of hog-backs, steep gradients, flat topped *Brachystegia tamarinoides* trees and thicket indicate this type on the photograph.

2. *Kikungu* (nduha in the Sukuma language). This is a non-lateritic red loam, occurring below the hog-backs or on the top of gentle sloping synclines. The soil is freely drained and considered short in available phosphate. The latter is said to be due to the fixation of the phosphorus in an unavailable form by the release of iron. The soil is used for growing tapioca (*Manihot utilissima*), corn, Indian millet (*Panicum miliaceum*), cow-peas, beans and ground nuts. Under peasant cultivation near Tabora, the "kikungu" soil is sometimes preferred to the "ichenga" for growing ground-nuts; but the former has the disadvantage of drying out quicker and cementing, so that the lifting of the crop is more difficult. On aerial photographs, the separation of these two soil types is sometimes impossible, especially as the boundary may be masked by cultivation. "Kikungu" is shown in Figure 3. It is recognized by its dark tone, relation to the hill-top soil, gentle slope of the ground and the general pattern of cultivation of the land. At Itobo, near Nzega, mango trees had been planted by the peasants along the boundary of the two soil types and this helped the delineation on the photographs. Tobacco grown on "kikungu" soil is considered to produce an inferior leaf for cigarettes than tobacco grown on "ichenga."

3. *Ichenga* or isenga (lusene, Sukuma). This is a light colored sandy soil, freely drained near the surface and occurring in catena sequence below the "kikungu" but above the herb line and illuvial soils. It seems to conform with Milne's plateau soil. Occasionally large white-ant hills are present. On aerial photographs the "ichenga" usually appears lighter in tone than the adjoining "kikungu" and "umanda"; but whereas it merges gradually into "kikungu," the change to "umanda" is abrupt. "Ichenga" is shown in Figure 3. Its light color, relation to "umanda," gentle slope and the general pattern of cultivation help in the interpretation. The soil is reported to be the most suitable economically for the large-scale growing of flue-cured tobacco. Peasant farmers grow corn, Indian millet, tapioca and ground nuts on "ichenga." Springs and wells are commonly located at the lower edge of this soil type.

4. *Umanda* (itogolo, Sukuma) occurs in catena sequence below the "ichenga," but above the "mbuga" soil. The ecological climax is considered to be wooded grassland. The soil is soft when wet, hard when dry but seldom cracks (c.f. "mbuga"). Near Tabora it can be described as a heavy silty loam. The soil is thought to be unsuitable for tapioca and ground nuts. Good crops of sorghum can sometimes be harvested. Where the shrub, *Commiphora camprestris*, is dominant the soil is very hard and considered

by the peasant farmers to be unsuitable for all crops. Sometimes this community can be recognized on aerial photographs. White ant-hills are often common in the "umanda," and easily recognizable on both single (Figure 3) and stereo-pairs of photographs. Good crops of corn, onions and other vegetables are grown in the vicinity of ant-hills, presumably due to the higher calcium content. On stereo-pairs of photographs, the "umanda" is identified by its catena sequence, pattern of cultivation, presence of ant-hills, occasionally visible herb-line and shade and texture of it in relation to the "mbuga" and "ichenga." It is often much simpler to delineate the combined "umanda" and "mbuga" soils from the "ichenga."

5. *Mbuga* occurs in the valley bottoms and is associated with the *Acacia-Combretum* grassland. It is a blackish, poorly drained soil, which is plastic when wet, cracking deeply when dry and frequently flooded in the rainy season. Included in this soil type are the sediments of the Quartenary Series found in the larger flood plains of the east. These are similar to the local "mbuga" on aerial photographs but cover much wider areas. In stereovision, the "mbuga" shows up as flat-bottom land without ant-hills along the lines of drainage. The shade is frequently distinctive (Figure 3), the texture is very smooth and often a definite pattern is produced by small cultivated paddy fields. Rice is an important cash crop. Good crops of sorghum are obtained; and south of Sikonge and northwards of Nzega the soil contains more sand and is capable of producing crops of sunflower seed for oil.

6. *Riverine* (alluvial) soil is extremely local and therefore not important. Although fertile, it dries out quickly. At Manonga, good crops of cotton and sorghum and a catch crop of dengu (Cicer spp.) have been obtained. On aerial photographs, the soil usually shows up distinctive along the lines of drainage, and permanent pools of water are sometimes seen (Figure 3). Along the drainage lines woodland species remain in leaf much longer so that on photographs taken early in the dry season the riverine areas are distinctive. Such areas are also distinctive where closed forest species occur, as these are evergreen and attain heights up to 100 feet.

Bee-keeping is very important in the vast unsettled areas of the woodland formation. *Julbernardia globiflora* is the principal source of honey and may constitute 30% or more of the trees of the *Brachystegia-Julbernardia* main type. As mentioned previously, this main type can be identified on the photographs, and this could possibly help in the siting of large bee-colonies. At Igombe River, photographs were used to locate permanent sources of water for siting large colonies.

6. Interpretation for Range Management

For this purpose, aerial photographs can help in at least three important ways. In unsettled areas, ecological types best suited to grazing by domestic animals can be located and the acreage estimated ahead of settlement. An example of this is the *Acacia-Combretum* grassland of the Nduha mbuga, which was deliberately excluded as part of a forest reserve to the east of Tabora as a result of carefully studying the aerial photographs. The photographs were also used at the same forest reserve to align stock routes across roadless country in relation to watering points, holding grounds and villages.

In settled areas, the photographs can help in assessing overstocking, and the area available for dry season grazing. On photographs of Nzega district, the sparseness of the vegetation and the incipient gully erosion indicated the area to be overstocked; and on this evidence the Veterinary Department introduced rotational grazing, as the people were opposed to a reduction in the head of stock. The area available for dry season grazing (a critical factor in stock-carrying capacity) can be roughly determined by delineating the boundaries of the "mbuga" soil; and from this the estimate of the wet season grazing can be made. Recognition of the main types of vegetation may also help in assessing the quantity of feed available. A possible classification for grazing is (a) mbuga grassland, (b) other grassland, (c) regeneration or thicket, (d) wooded grassland.

In the control of disease, the photographs also help. For example, the common tsetse fly, *Glossina morsitans*, is often a serious threat to animal health in areas of new settlement. Glossina is the carrier of sleeping sickness of humans and *Trypanosomiasis* of domestic animals. For breeding the common tsetse requires a two-story canopy of vegetation, usually provided by shrubs and large trees; and can be controlled by eradicating one of the stories in advance of settlement. These areas of two stories can usually be recognized and delineated on aerial photo graphs; and commonly comprise the interzone,[4] ant-hill thicket, riverine thicket and sometimes regeneration.

In conclusion, it may be added that aerial photographs can contribute towards the preservation of wild animals by providing an assessment of the more important ecological types for feeding and their location. For example the kudu prefer white-ant hill areas, and reed buck remain on the wooded grassland and *Acacia-Combretum* grassland throughout the year. Other animals, e.g. elephant, eland and roan migrate annually; and, for example, near Tabora pass during the critical dry months on the wooded grassland of the Ugala river. It is at such times

that they are most vulnerable to slaughter by man. By locating and delineating these areas on the photographs, protection of the game on the ground is facilitated. Different species of grasses, e.g., *Sporobulus* and *Themeda*, burn at different times; and it might be possible to fly areas to assess each separately. Occasionally, a single grassland community is known to be preferred. At higher elevations, buffaloes prefer *Pennisetum clandestinum* grassland for grazing in the dry season.

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