# CARRYING CAPACITY ON TIKOPIA ISLAND

*KIRSTEN HERVAD-JØRGENSEN*

Hervad-Jørgensen, Kirsten: Carrying Capacity on Tikopia Island. Geografisk tidsskrift 76: 88-95. København, juni 1, 1977.

*On the basis of two aerial photographs of the island of Tikopia, information on population, standard energy consumption, knowledge of the food pattern, the agricultural system and yields/ha it has been attempted to estimate the areas necessary for food production. To verify the assessed values, they have been put into various formulas for estimation of carrying capacity. The consistency of the values turns out very well and the used methodology might be a possible way to estimate carrying capacity with limited means.*

Kirsten Hervad-Jørgensen, M. Sc. Geographical Institute, University of Copenhagen, Haraldsgade 68, DK 2100, Copenhagen Ø.

This paper is based on a M.Sc. thesis on Tikopia Island, a tiny Polynesian outlier in the British Solomon Islands. It is situated at about 168°, 48' E and 12°, 18' S according to the 'Pacific Islands Pilot'. The island is well-known from the classical ethnographical works by Professor Raymond Firth. The island was chosen for a theoretical investigation as the results could be compared with descriptions of the island. Furthermore, the Tikopia have for a long time been fully aware of the relation between area and population. According to that they have practised 'fakatau ki te kai', which means 'making the population in accordance with the amount of food', i.e. practised birth control by variuos means. The results could therefore be put into formulas for estimating carrying capacity and be compared with the actual population in 1929, which could be assumed to be adjusted to the then available amount of food to some extent.

The aim to make a quantitative estimate seemed from the beginning to be a quite impossible task, as the quantitative sources were only few. The ethnographical works on the island contained fascinating descriptions, but had no exact information regarding production and consumption. The sources for making quantitative estimates, were restricted to:

1. Two aerial photograps (at scale approx. 1:60,000) from 10-7-1962. They were analysed by means of a Zeiss Interpretoscope in order to distinguish the agricultural regions and their degree of utilization. One enlargement (scale approx. 1:15,000) was used to measure the total

## Resume

*Ud fra begrebet bæreevne for befolkning vises, hvorledes arbejde indgår både som bestemmende for produktionen og som en stofskifteudgift. Hvis sidstnævnte medtages, fås en formel for maximum bæreevne målt i biomasse* $P_{max} = A \cdot \frac{y - c_w}{c}$*, hvor A er det producerede areal, y spiseligt udbytte pr. arealenhed,* $c_w$ *arbejdsudgiften og c forbruget pr. kilo biomasse. Fig. 1 viser, at maximum bæreevne opnås ved en bestemt arbejdsindsats, som dog i subsistenslandbrug normalt ligger under den maksimalt til rådighed værende. Udover direkte produktionsarbejde er især transport af betydning. Transportarbejdets betydning for spredte lodder fremgår af de udledte formler og af fig. 2. Af fig. 3 ses, at den effektive arbejdstid på denne måde kan blive ret begrænset.*

*Til slut vises det, at man selv ved korte distancer til spredte lodders dyrkning kan opnå fordel ved at benytte mere end én bopæl. På den polynesiske ø Rennell (Mugaba) er der til hver landsby inde i landet knyttet en eller flere ved kysten (fig. 4), hvortil landmændene migrerer. Besparelsen i arbejdstid er større end udgiften til ekstra bolig, hvad angår landsbyen Hatagua (tabel 2). Denne type kan evt. betegnes som 'sæsonvandrende flyttemarksbrug'.*

## Literature

*Allan, W.* (1967): The African Husbandman. London.

*Christiansen S.* (1975): Subsistence on Bellona Island (Mungiki). Fol. Geogr.Dan. vol. XIII, Copenhagen.

*Christiansen, S.* (1976): Potential Crop Production and Carrying Capacity for Population; Basic Concepts in Cultural Geography. Congress Paper before the XXIII IGU Congress, Odessa.

*FAO/WHO, 1973:*Energy and Protein Requirements. Rome.

*Fanger, P. O.* (1970): Thermal Comfort. Copenhagen.

*Hägerstrand, T.* (1976): The Space-Time Trajectory Model and Its Use in the Evaluation of Systems of Transportation. Transport as an instrument for allocating space and time – a social science approach. The Inst. of Public Finance, Techn. Univ. of Vienna, No. 11. Vienna.

*Whittlesey, D.* (1937): Fixation of Shifting Cultivation. Econ. Geography, vol XIII: 139-154.

area of the island and the various agricultural regions. An outline map was drawn on basis of this photo. The division of the land area into regions of which some are used for agricultural purposes, some probably not or only to a limited degree, may of course be a controversial matter as the divisions are based on a synthesis of the information drawn from the literature on agricultural systems in that part of the world and from the aerial photographs, but not on personal investigation on the island. The elaboration of the outline map was complicated because it was necessary to transfer the three-dimensional impression from the interpretoscope to the enlargement by means of transparent paper, which blurred the details.

2. Records of the Tikopian population by age and sex for the years 1929 and 1952, which made it possible to estimate the requirements of energy and protein of the Tikopia fairly accurately.

3. Values for estimating these requirements, which were found in FAO/WHO's 'Energy and Protein Requirements', 1973.

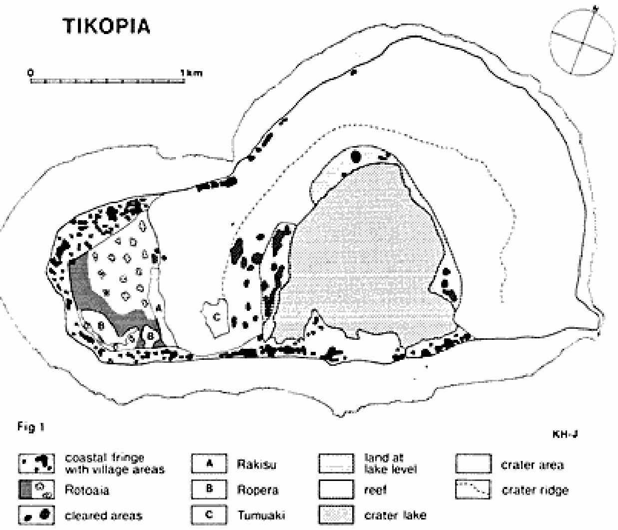
*Agricultural Regions*

From the aerial photograph and fig. 1 it appears that Tikopia can roughly be divided into af few important regions: The crater area, the southern plateau and the coastal fringe with the village areas. The cultivated areas are found within the two first mentioned regions and according to Barrau (1962) within two types of ecological classifications.

1. The crater area with tropical rainforest. This type is found at an altitude below 1,500 m. and has a precipitation exceeding 2,500 mm. The cultivation system is bush-fallowing rotation and the predominant cultivated plant is taro.

2. The southern part of the island with its calcareous soil, where scarce fresh water resources limit the possibilities for cultivation.

The total crater area seems to be under cultivation to various degrees even in the northern and most inaccessible part of the island. According to R. Firth, the utilization of the crater slopes is named orchards, contrary to garden areas. The slope gradients vary from 20° to 45°. In an orchard the tree crops, as for example breadfruit, coconuts, papermulberry tree and areca palm will often be the primary resource and taro the secondary. Fig. 2 is given as an example of the utilization of a crater slope. The period of fallow in bush-fallowing rotation is usually from 10-15 years, which presumably is too long a period in relation to Tikopia realities and needs. The soils of the crater area have been developed on volcanics of andesitic composition, which should allow a more frequent cultivation. The crater area includes a minor area, Tumuaki, which seems to be under permanent cultivation.




The southern part of the island includes orchards in Rotoaia and minor garden areas under supposed permanent cultivation. The garden areas are: Ropera, obviously waterlogged to some degree, and Rakisu, situated at the foot of the crater and therefore provided with a better soil and a more favourable water balance than the rest of the southern part of the island. Fig. 3 may serve as an illustration of the utilization of the southern part of the island.

Furthermore there are some minor cultivated areas at the crater lake. Taro (Colocasia esculenta and Cyrtosperma chamissonis) is the predominant crop here and on the permanently cultivated areas.

The coastal fringe with village areas has been considered of too little agricultural importance to be included in the calculations.

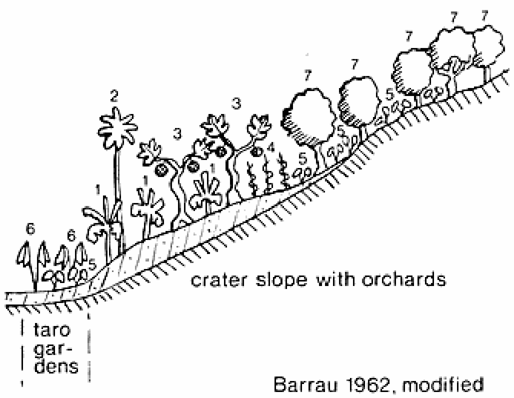



Fig. 2. Utilization of the crater slope.
Fig. 2. Udnyttelse af kraterskråningen.

1. Banana plant (Musa sp.)
2. Coconut palm (Cocos nucifera)
3. Breadfruit (Artocarpus sp.)
4. Yam (Dioscorea sp.)
5. Taro (Cyrtosperma sp.)
7. Trees for remaining subsistence production.

## Calculation of the energy and protein requirements

As it has not been possible to get any detailed information of the actual comsumption of food neither concerning quantity nor composition, it has been necessary to try to estimate the requirements by standard figures. According to those, corrections for temperature and age have been made. The activity is assumed to be moderate. Moderate activity was considered justified, as the Tikopia according to the descriptions seem to have a good deal of leisure time to spend on their social life. For the 1929 population of 1278 persons the total necessary energy requirement amounted to about 1,055 × 10.6 Mcal and the total necessary protein requirement to 14,390 kg high quality protein, which gives an average of 2260 kcal/cap./day and 31 g high quality protein/cap./day. The year 1929 was chosen for the further calculations as the description of the society at that time (Firth, 1939) seems to reflect a stable agricultural system contrasting the description from 1952 (Firth, 1959), which reflects a society suffering from population pressure.

In 1952 the necessary energy requirement amounted to about 1,462 × 106 Mcal and the necessary protein requirement to 19,990 kg high quality protein. The population was 1753 persons, which according to FAO standards gives an average of 2285 kcal/cap./day and 31 g high quality protein/cap./day. It will later be shown by the formulas that the island could not support a population of that size. The main problem was to provide an ample calorie supply, while the protein production according to the calculations already in 1929 was nearly great enough to meet 1952 needs (table 1).

## Assessment of the composition of the diet

The common food items are edible root, coconuts, breadfruit, bananas, fish and wild fruits. Their relative importance for consumption is seen on fig. 4. It was found most reasonable to try to estimate the share (in %) of each food item in the daily requirement. By doing this it was possible to calculate the quantity necessary to cultivate and consequently the areas needed, taking into conside-

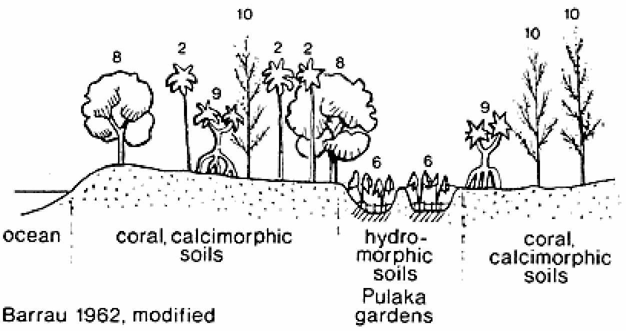



Fig. 3. Utilization of the southern plateau
Fig. 3. Udnyttelse af det sydlige plateau.

8. Calophyllum sp.
9. Pandanus sp.
10. Casuarina sp.

| % of kcal | | kcal cap/day | grammes cap/day | preparation loss grammes | preparation loss % | gross production/kilos cap/day | gross production/kilos per year |
|---|---|---|---|---|---|---|---|
| 50 | Taro | 1130 | 1153 | 128 | 10 | 1.281 | 597,548 |
| 9 | Breadfruit | 203 | 193 | 21 | 10 | 0.215 | 100,291 |
| 13 | Coconut meat | 294 | 85 | - | - | 0.085 | 39,649 |
| 7 | Banana | 158 | 160 | 78 | 33 | 0.238 | 111,020 |
| 4 | Wild fruits | 90 | 43 | 4 | 10 | 0.047 | 21,924 |
| 7 | Fish | 158 | 95 | 16 | 15 | 0.111 | 51,778 |
| 5 | Yam | 113 | 112 | 20 | 15[2] | 0.132 | 61,574 |
| 5 | Manioc, Sago | 113 | 94 | 11 | 10 | 0.105 | 48,979 |
| | | 2259 | 1935 | | | 2.214 | 1,032,763 |

[1]) (+8020 x 0.45). [2]) incl. planting material. [3]) 808 kilos/cap/year.

Protein Requirements:

According to FAO/WHO (1.45 value) 45 g/cap/day
--- " --- high quality 31 g/cap/day

Produced according to supposed composition of food (1.45 value) 59 g/cap/day
--- " --- high quality 40 g/cap/day

Necessary protein production 1929 (1.45 value) 20,869 kilos.
--- " --- 1952 -"- 28,988 kilos.

ration their degree of utilization. It must be noted that possible misjudgements in the assessment of the different food items' share of the daily consumption will influence all further calculations. The percentage composition of the calorie requirement for a Tikopia appears from fig. 5. The share of roots amounts to 60%. It is less than the estimated consumption in nearlying areas (Barrau, 1958). However, a higher percentage of taro would demand about 1/5 of the island's entire area (calculated on basis of the planting distance). With a daily consumption of two taros/cap., as suggested by R. Firth, the calorie percentage would amount to only 38% which is considered to be an underestimate. Breadfruit constitutes a greater wuantity of the food items than do coconuts, but the calorie content of cocos is greater.

The share of fish in the diet might have been considered too high. The estimated gross production without surplus amounts to about 52 tons and for comparison it can be mentioned that the estimated gross production on Bellona (also in the Solomon Islands) amounts to 60 tons for a much smaller population. If one supposes that an active fisherman on Tikopia, as on Bellona, in the period September through March catches 100 kg, it would total a catch of about 40 tons for that period. This would correspond reasonably with a gross production of 52 tons for the whole year.

Without direct samples it is not likely that much could be changed in the estimated composition of the diet. Apparently there seems to be a real background for R. Firth's statement on the healthy appearance of the

Taro (Colocasia sp.)
Breadfruit
Coconut
Banana
Pulaka (Cyrtosperma sp.)
Sago
Yam

Fig. 4. Quantitative Importance for consumption. (Firth, 1939).

Fig. 4. Mængdemæssig betydning for forbrug. (Firth, 1939).

| dible production er year in kilos | dry matter production per year in kilos | protein production per year in kilos (1.45 value) |
|---|---|---|
| 537,840 | 145,217 | 10,218 |
| 90,029 | 27,009 | 1,440 |
| 39,649 | 19,467 | 1,387 |
| 74,635 | 19,480 | 896 |
| 20,058 | 8,023 | 581 |
| 44,315 | 12,762 | {8,020 3,609[1] |
| 52,245 | 13,845 | 1,097 |
| 43,848 | 13,154 | 307 |
| 902,619 | 258,957 | 27,555* |
| grammes/cap/day. | | |

Table 1. Calculation of total food requirement on the basis of 1278 persons' daily calorie consumption and calorie distribution. Daily consumption = 2260 kcal.

Tabel 1. Beregning af totalt fødevareforbrug på basis af 1278 personers daglige kalorieforbrug og kaloriefordeling. Dagligt forbrug = 2260 kcal.

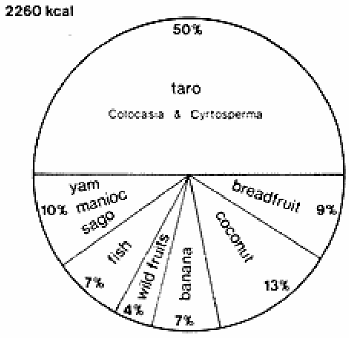



Fig. 5. Percentage calorie composition of daily energy requirement.

Fig. 5. Procentvis kaloriesammensetning af dagligt energibehov.

Tikopia. The limited land resources and the easy access to lake and sea seem to secure an appropiate composition of the diet concerning animal protein.

### Calculation of the necessary amounts

From different sources (U.S. Dept. for Agric. 1963 and 1975, Wissenschftl. Verlagsgesellsch. 1962) the nutritive values of the different food items were calculated and the results used to estimate a yearly necessary gross production. The calculations appear from table 1. This production, it must be stressed, represents only the adequate necessary daily intake of energy and is without a normal surplus, which could be of great importance on Tikopia. In 1929 the island relied totally on its own resources, as it probably still does.

In this table also the dry matter content of the various food items appear, which was used to calculate the corresponding protein production. As the protein from roots is of a rather poor quality the calculations are given as 1.45 values. This means that to provide 1 kg high protein 1.45 kg. root protein is needed. In the table only fish meat has been regarded as high quality protein. As some plant items are considered to have a protein content of higher quality than that of roots, it follows that the calculated protein production rather tens to be underestimated. Nevertheless the protein production more than met the requirements in 1929.

To the supposed composition of the diet corresponds a daily protein intake as shown on fig. 6. The daily consumption equals 40 g high quality protein, while the necessary consumption only amounted to 31 g high quality protein. This might be due to errors in the percentage composition of the food items or the Tikopian diet might be well composed. In the composition of the diet it has, however, been taken into consideration that roots are 'staple food', as taro, yam, manioc and sago (palm) constitute 60% of the daily energy intake, where 60-80% are considered normal for the area. In R. Firth's descriptions it is stated that breadfruit and bananas were eaten in rather considerable quantities and furthermore they were stored as pastes for periods of scarcity. Cocos was used for the daily meals as cream and there was no export of copra from Tikopia. In times of scarcity the different wild fruits, some with high nutritive values, played a considerable role. Fish made op 7% of the daily energy requirement, while its high protein content made the item constitute as much as 42% of the protein intake.

### Estimations of the area necessary for agriculture production

The land area of Tikopia was by R. Firth stated to be something less than 3 sq.miles (~7 km²) corresponding to a population density (1929) of more than 400/sq.m. or 165/km². The area measured of the island is about 4,42 km², which corresponds to a population density of 290/km² in 1929. It raised the question whether the agricultural system could be in balance at that time, as there is no possible way to extend the available area. Nothing in the description from 1928-29 indicated in any way it should not be, although, as will be shown later, it must have been a delicate balance and food was not abundant. In the traditional way it was part of all rituals and feasts and no restrictions were observed in the tradi-

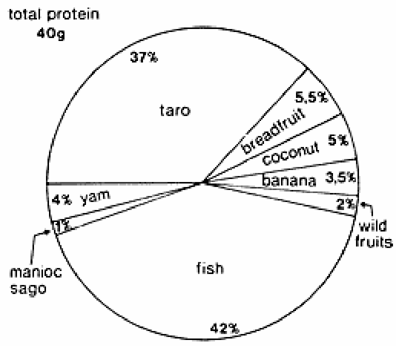



Fig. 6. Percentage protein composition of daily intake.

Fig. 6. Procentvis proteinsammensetning af daglig tilførsel.

tional right to use the land of other people. The 'fakatau ki te kai' system worked by various social mechanisms.

From the amount of necessary production of the different food items, yields/ha and minimum rotation length, the area necessary per cap. amounts to 0.27 ha (table 2). The area necessary/cap./year amounts to 0.075 ha, which is in no way contrasting the estimated values in nearlying areas (Barrau, 1961, Christiansen, 1975). From this follows that the total necessary area for agricultural production to feed a population of 1278 persons amounts to about 345 ha. This means that only about 95 ha will be left for wild fruits, for materials to be used in the remaining subsistence production and for village areas.

In order to find the actual areas it was tried to estimate the cultivation intensity of the different areas. The necessary area was 0.075 ha/cap./year. Rakisu and Ropera were assumed to be permanently cultivated, whereas Rotoaia had a rotation length of 3 years. There were minor cultivated areas at the lake and on the top of the ridge at Tumuaki. Together those areas contributed with about 0.02 ha/cap. The rest must be taken from the crater slope. Under the assumption that it was cultivated under bush-fallowing rotation with a rotation length of at least 10 years, the crater area would contribute only about 0.02 ha/cap. If the figure 0.075 ha/cap. should be fulfilled it indicates a much shorter rotation in the crater area. In order to provide the necessary areas, the rotation length should not exceed 5 years. Owing to the fertile soils derived from the andesitic rocks of the crater area, it is likely that the agricultural system may be stable even with a so short fallow period. Taro being the predominant crop with a rotation length of at least 4 years, all calculations point in the direction that the island was already in 1929 exploited to a maximum degree and that the population size, too, was near its maximum if there should not be a deterioration of the agricultural system.

With pieces taken from the different works by R. Firth it was tried to make a jigsaw puzzle. 345 ha or 0.27 ha/cap. turned out to be an interesting figure. The pieces were provided from a table of group membership of the four chiefly houses, a statement on area relationship

| | Necessary production in kilos | Necessary area in hectares/year | Minimum rotation length | Necessary area incl. fallow, hectares |
|---|---|---|---|---|
| Taro | 597,548 | 67.2 | x 4 | 268.8 |
| Breadfruit | 100,291 | 10.0 | | 10.0 |
| Coconut meat | 39,649 | 8.97 | | 8.97 |
| Banana | 111,020 | 3.42 | x 7 | 23.94 |
| Yam | 61,574 | 3.86 | x 6 | 23.16 |
| Manioc, sago | 48,979 | 2.72 | x 4 | 10.88 |
| | | 96.17<br>0.075 ha/cap. | | 345.75<br>0.27 ha/cap. |

Total land area 442 hectares. Cultivable area 390 hectares (coastal fringe with village areas 52 hectares).

Table 2. Area requirements. Tabel 2. Arealbehov.

between the four chiefs 1:6:6:3 (Fangarere, Taumako, Tafua, Kafika) (Firth, 1939) a sketch map of Rasiku (Firth, 1959) and an information that Ariki Fangarere commanded 6 orchards of 4 ha each (Firth, 1936). The total land area of the Fangarere clan amounted to 24 ha plus a little more than 0.2 ha measured in Rasiku. That provides each member of the clan (89 persons) with 0.27 ha. Regarding the area relation between the clans the total area commanded by them will be 387 ha. The total island minus the coastal fringe with village areas amounts to about 390 ha. As the area requirement to feed the whole population in 1929 was 345 ha this indicates that the Fangarere clan was a little worse off than the other clans and that the Tikopia were fully aware of the man/land ratio necessary to provide an adequate food supply. It can be mentioned that R. Firth's statement on the island's area to be something less than 3 sqm. (approx. 7 $km^2$) could have been suspected to be wrong by using the figures concerning the area relationship between the four clans.

## Estimation of carrying capacity

In order to try the reliability of the calculated values from Tikopia (table 1, 2 and set up below), formulas put forward by variuos authors have been used. The aim of using different formulas has been to test the consistency of the found values. In whatever formula they are put, the results point in the same direction. The original formulas are used and the variables mentioned with Tikopia values in parantheses. It will be mentioned in the following text if the formulas are alike or deviate from one another in the use of variables.

The data used are:

| | | | |
|---|---|---|---|
| Total area | 442 ha | | |
| Cultivable area | 390 ha | 88% of total area | |
| Area/cap./year for food production | | | 0.075 ha |
| Area/cap./year including fallow | | | 0.27 ha |
| Necessary gross production/cap./year | | | 808 kg |
| Necessary fallow for predominant crop | | | 3 years |
| Total population | 1929 | | 1278 persons |
| | 1952 | | 1753 persons |
| Population density | 1929 | | 291/$km^2$ |
| | 1952 | | 396/$km^2$ |

## Normal surplus

Allan's 'subsistence law' says that local production equals consumption + normal surplus in a given food producing system.

a = area (390 ha)

p = population (1278 and 1753)

y = yields/ha in tons

c + n = consumption + normal surplus (50%) (1212 kg)

With the 1929 population

$$y = \frac{p(c+n)}{a} \sim 4.0 \text{ t/ha}$$

With the 1952 population

$y = \frac{p(c+n)}{a} \sim 5.7$ t/ha

If the rotation length for the whole area is 4 years it corresponds with yields of 16 t/ha and 23 t/ha. Both yields are high and 23 t/ha for the entire area seems quite impossible to attain. Anyhow only a very small surplus is likely to be incorporated in the Tikopian agricultural system.

To find the area necessary for a person in a given area, *W. Allan* gives the expression: $100\,\frac{CL}{P}$

P = cultivable percentage

C = cultivation factor $\left(\frac{\text{fallow period + cultivation period}}{\text{cultivation period}}\right)$

L = cultivated area/cap.

Area/cap.: $\left(100 \times \frac{4 \times 0.075}{88}\right)$ ha $\sim$ 0.34 ha (0.27 ha)

In order to find the critical population size (Cs) and the critical population density (Cd) Conklin uses the following variables:

| | |
|---|---|
| A = min. cleared area/cap./year | (0.075 ha) |
| L = max. cultivable area | (390 ha ) |
| T= min. rotation length | (4 years ) |

$Cs = \frac{L}{AT} = \frac{390}{0.075 \times 4} = 1300$ persons (1278 persons)

$Cd = \frac{Cs}{L} \times 100 = \frac{1300 \times 100}{390} = 333/km^2$ $(328/km^2)$

$333/km^2$ are for cultivable land. It corresponds to a poulation density of the total area of $293/km^2$, matching very favourably with the $291/km^2$ on the total area and the $328/km^2$ on cultivable land found in 1929.

Derived from the first formula the min. length of rotation T can be found (the population of 1929 is used). The result will ve interesting in a context later in the text.

$$T = \frac{\frac{L}{Cs}}{A} = \frac{\frac{390}{1278}}{0.075} \sim 4 \text{ years}$$

The min. length of rotation with a population of 1753 persons will be 3 years. These calculations indicate that in 1929 Tikopia had a population near its maximum size under the given cultivation system. To consider a cultivation to be stable under humid tropical conditions with rotation lengths of less than 4 years seems quite unrealistic, unless the major part of the island was changed into paddy terrasses. Cash cropping by producing copra, as is common in other places of Oceania, is beyond the limits of area possibilities.

To estimate the potential population density under different types of shifting cultivation, P. Gourou puts the following formula:

$\frac{A \times C}{B}$ where

A = the cultivable area/the total area (0.88)

B = rotation length (4 )

C = inhabitants/ha cleared/year (1 : 0.075 ~ 13)

Potential population density $\frac{0.88 \times 13}{4} \times 100 = 286/km^2$ $(291/km^2)$

Beguin uses his formulas to calculate the maximum population *p* and the maximum population density *d*.

Potential production *v* = maximum agricultural production from a given obtainable area in an existing agricultural system. *v* is calculated as

$\frac{P}{c+j}$ where

P = production on the cultivated area/year (taro 8.89 t/ha)

c = cultivated area/year (1 ha )

j = the corresponding fallow (3 ha )

$\underline{v} = \frac{8.89}{4} \sim 2.22$

Beguin estimates the necessary area *s* for a population *p* to get an output/year *u* practising an agricultural system with the potential *v*.

$s = \frac{pu}{v} = \frac{1278 \times 0.808}{2.22} \sim 465$ ha (442 ha )

In order to calculate the population size *p* in a limited area *s* with a known potential *v* and a per cap. production/year *u*, Beguin uses the following formula:

$p = \frac{sv}{u} = \frac{442 \times 2.22}{0.808} \sim 1214$ persons (1278 persons)

For calculation of the maximum population density $\underline{d}$, given the potential $\underline{v}$ and a per cap. production/year $\underline{u}$, the formula

$d = \frac{v}{u}$ is used.

$d = \frac{2.22}{0.808} \times 100$ $275/km^2$ $(291/km^2)$

Beguin's more sophisticated formulas have not been found useful, as detailed figures for Tikopia are not available without investigations in the place.

The last method to calculate carrying capacity to be mentioned is *Carneiro's*, who also calculates whether the agricultural system can be permanent within the given area or not. His variables are:

A = area/year for the production of food for one person
P = population

Y = cultivation period
R = fallow length
T = total cultivable area within walking distance from the habitations
L = the time the habitations can be permanent according to the demands of the cultivation system.

On these suppositions the population that can live permanently in an area is:

$$P = \frac{\frac{T}{(R+Y)\times Y}}{Y} = \frac{\frac{390}{(3+1)\times 1}}{0.075} = \begin{matrix}1300 \text{ persons} \\ (1278 \text{ persons})\end{matrix}$$

To calculate the smallest area of cultivable land for a habitation of a given size, where the place can be permanent, the following formula is used:

$$T = \frac{P \times A}{Y} \times (R + Y) = \frac{1278 \times 0.075}{1} \times (3 + 1) \sim 383 \text{ ha}$$

(390 ha)

To know how long time a society can stay in the same area before impoverishing of the soil forces it to move Carneiro uses:

$$L = \frac{T}{\frac{P \times A}{Y}} = \frac{390}{\frac{1278 \times 0.075}{1}} \sim 4 \text{ years}$$

The rotation length for the predominant crop on Tikopia is 4 years. If the population is 1753 as it was on Tikopia in 1952, $L \sim 3$ years. If $L \geqq (R + Y)$ the area can be occupied indefinitely. On Tikopia R + Y are estimated and according to Carneiro's formula it gives a delicate balance. The population in 1952 will be too numerous to stay in the area under a stable agricultural system. It can be remarked that this calculation equals the derived formula to estimate the necessary rotation length, which is in no way surprising as the rotation length is of decisive importance in this respect.

### Formulas regarding total population, area and population density

Considering the formulas regarding the total possible population of an area, those set up by Conklin and Carneiro are identical. They put cultivable area in relation to necessary area/cap., while Beguin finds the population by means of a potential production/ha i relation to consumption/cap., which is a refinement, but does not contrast with the former, as the potential production versus consumption is closely connected with the necessary area/cap..

A further look at the formulas regarding the area and population density will show the same features as the formulas regarding total population. What is interesting is that the calculated values for Tikopia are put into new connexions, which show that they, though independently calculated, are consistent.

The formulas as a whole can be said to be derived from Production = Consumption, i.e. Area × yield = Population × consumption (Allan). From this follows that $P \sim A \times \frac{Y}{c}$ or $A \sim \frac{P \times c}{y}$ (Beguin).

Regarding area calculation also a rotation factor and a land use coefficient can be added (Allan and Carneiro), and likewise regarding population calculation (Conklin and Carneiro).

The conclusion to be drawn, after having controlled the calculated values in the expressions regarding carrying capacity, is that in the year 1929 Tikopia had a population near its possible maximum if it was to be fed properly. Having no further area resources, a population of 1753 (1952) would mean a severe strain on the agricultural system. The area necessary to feed the population to the same standard would then amount to $\sim$ 475 ha, which is more than the island's entire area. The very short rotation length that is obviously incorporated in the Tikopian agricultural system, can be explained by the fact that most of the soils in the island are of volcanic origin.

### Later changes

The growth in population from 1929 to 1952 amounted to 37%. Besides the changes that followed in the agricultural system, the situation became critical in 1952 when Tikopia was severe struck by a hurricane, which caused great damage to the crops and soon created an acute hunger situation. Probably this critical situation contributed to an extremely high infant death rate.

The pressure on ressources had since 1929 changed the cropping patterns, especially did manioc and sweet potatoes replace taro. In the long run this will lead to a depreciation in the diet with regard to protein supply, which will affect especially the young generation. After the hurricane food production was not back to normal until after a year and then shortly afterwards the island was struck by another hurricane. During a part of the year 1952 Tikopia was in need of supplies from the outside world and only their strong social organisation prevented a total breakdown of their system.

In that situation the introduction of manioc and sweet potatoes helped to make the food situation less catastrophic, as the first could be stored in the ground and the latter could give quick yields, while the taro leaves were spoiled and new planting material had to be provided from outside the island.

The situation was of course severely aggravated by the hurricane, but from the description from 1952 it appears that there had been a great reduction in the fallow areas compared with 1929. In addition, in 1952 owner and cultivator was to a much greater extent the same person. There had not been a change in the formal rights, but in the exercise of them. Those changes were not a result of the hurricanes, but of a strong population pressure on resources. As also the calculations show, the agricultural system cannot remain stable with a population of about 1700 persons as the available resources are extremely limited. The stability of a system of this kind is dependent on a refined selection of the plant material of any kind. Tikopia's transformed ecosystem can probably support about 250 persons/km² given the fertile soil, the amount of precipitation, permanent cultivation in minor areas and an appropiate fallow length in the remaining areas. Information from 1965 state that this year about 1000 persons were living on Tikopia, while about 500 were working in coconut plantations in the Russel Islands and in the Solomon Islands. The reduction in population of about 200 persons since 1952 was brought about by a severe influenza and malaria epidemic in the mid-fifties.

### Conclusion

From a known population, estimated yields (standard figures might be established), consumption calculated by FAO standard figures and a total area derived from aerial photographs, it has been possible to find the areas necessary for cultivation and following the carrying capacity of the island under the given agricultural system. This leads to the thought that the methodology (maybe with some refinements) might be a possible way to estimate carrying capacity in areas with different agricultural systems too, without detailed and expensive investigations on the place. Tikopia problems were found especially workable as the descriptions to a certain degree made it possible to compare the estimated values with realities.

### RESUME

Artiklen er et sammendrag af en opgave fra sommeren 1976. Tikopia tilhører Salomon øerne og er beliggende på 168°48' østlig længde og 12°18' sydlig bredde. Øen er velkendt fra professor Raymond Firth's klassiske etnografiske værker. Tikopianerne har igennem lang tid på grund af øens begrænsede areal taget hensyn til forholdet mellem areal og befolkning ved at praktisere fødselskontrol.

Det var vanskeligt at foretage en kvantitativ beskrivelse, da kilderne hertil var få: To luftfotografier fra 1962, en artikel med befolkningsopgørelse på køn og alder i 1929 og 1952 og FAO standard tal til beregning af kalorie- og proteinbehov.

På basis af luftbillederne blev øens totale areal og størrelsen af de enkelte landbrugsregioner beregnet. Inddelingen fremgår af fig. 1. Befolkningens nødvendige kalorie- og proteinforsyning blev beregnet og derudfra et gennemsnitsforbrug. Sammensætningen af dette antoges at være som det fremgår af fig. 5. Herudfra beregnedes de nødvendige mængder for hele 1929 befolkningen. Beregningerne fremgår af tabel 1. Det fremgår heraf, at med den antagne sammensætning af diæten er proteinforsyningen for 1929 næsten stor nok til at dække 1952-behovet. Af fig. 6 fremgår det at diæten synes godt sammensat med hensyn til animalsk protein, hvilket kan forklares ved begrænsede landressourcer og let adgang til havet.

Udfra den nødvendige produktion af fødevarer beregnedes arealet til at dyrke denne mængde. Resultatet var at 0.27 ha/cap. og 0.075 ha/cap./år var nødvendigt (tabel 2). For at skaffe de nødvendige arealer må rotationslængden i kraterområdet ikke overstige 5 år, hvilket er en kort periode og formentlig kun er muligt på grund af en frugtbar jordbund.

For at prøve at beregne værdiers sammenhæng blev de indsat i forskellige bæreevneformler. Alle resultater pegede henimod at Tikopia i 1929 havde en næsten maksimal befolkning, mens befolkningen i 1952 var så stor, at den ikke kunne ernæres på øen uden en forringelse i dyrkningssystemet. Den på øen bosiddende befolkning er senere stabiliseret på ca. 1000 personer, mens omkring 500 arbejder i kokosplantager på andre øer. Den gode overensstemmelse, der er imellem de beregnede værdier og de indtryk der kan fås fra de etnografiske beskrivelser, kunne betyde, at det vil være muligt med disse afgrænsede midler at beregne bæreevne også i andre områder.

### REFERENCES

Agriculture Handbook nr. 8 (1963). Agricultural Research Service, U.S. Department for Agriculture.

Agriculture Handbook nr. 456 (1975). Agricultural Research Service, U.S. Department for Agriculture.

*Barrau, J.* (1958): Subsistence Agriculture in Melanesia. B.P. Bishop Mus. Bull. 219, Honolulu.

*Barrau, J.* (1961): Subsistence Agriculture in Polynesia and Micronesia. B.P. Bishop Mus. Bull. 223, Honolulu.

*Barrau, J.* (1962): Les Plantes alimentaires de l/Océanie, origines, distribution et usages. Marseilles.

*Beguin, H.* (1964): Modèles Géographiques Pour l/Espace Rural Africain. Bruxelles, Akadémie Royale des Sciences d'Outre-Mer.

*Borrie, W.D., Firth, R., Spillius, J.:* The Population of Tikopia, 1929 and 1952. Population Studies, vol. 10. London 1956-57.

*Carneiro, R.L.* (1956): Slash-and-Burn Agriculture: A Closer Look at its Implications for Settlement Patterns. Men and Cultures, 5th Int. Congr. of Anthr. and Ethnol. Sciences.

*Christensen, S.* (1975): Subsistence on Bellona Island. Folia Geographica Danica. Tom. XIII, Copenhagen.

*Clarke, W.C.* (1971): Place and People. An Ecology of a New Guinean Community. Univ. of Calif. Press.

*Conklin, H.C.* (1957): Population-Land Balance under Systems of Tropical Forest Agriculture. Proc. of the Ninth Pacif. Congr. Vol. 7.

Die Zusammensetzung der Lebensmittel, I-III. Wissenschaftliche Verlagsgesellschaft. M.B.H. Stuttgart.

FAO/WHO (1973): Energy and Protein Requirements. Rome.

*Firth, R.* (1936): We, the Tikopia. Allan and Unwin. London.

*Firth, R.* (1939): Primitive Polynesian Economy. Routledge. London.

*Firth, R.* (1959): Social Change in Tikopia. Re-Study of a Polynesian Community after a Generation. Allan and Unwin. London.

*Henshall, J.D.* (1967): Models of Agricultural Activity. In Chorley and Haggett: Models in Geography. Methuen. London.

*Koch, P.H.* (1970): Die Shifting Cultivation und Ihre Luftbildauswertung. Juris Verlag. Zürich.

*Larson, E.H.:* Tikopia Plantation Labour and Company Manament Relations. Oceania, vol. 40. 1969-70.

*Waddell, E.* (1972): The Mound Builders. Univ. of Washington Press.

limited. The stability of a system of this kind is dependent on a refined selection of the plant material of any kind. Tikopia's transformed ecosystem can probably support about 250 persons/km² given the fertile soil, the amount of precipitation, permanent cultivation in minor areas and an appropiate fallow length in the remaining areas. Information from 1965 state that this year about 1000 persons were living on Tikopia, while about 500 were working in coconut plantations in the Russel Islands and in the Solomon Islands. The reduction in population of about 200 persons since 1952 was brought about by a severe influenza and malaria epidemic in the mid-fifties.

## Conclusion

From a known population, estimated yields (standard figures might be established), consumption calculated by FAO standard figures and a total area derived from aerial photographs, it has been possible to find the areas necessary for cultivation and following the carrying capacity of the island under the given agricultural system. This leads to the thought that the methodology (maybe with some refinements) might be a possible way to estimate carrying capacity in areas with different agricultural systems too, without detailed and expensive investigations on the place. Tikopia problems were found especially workable as the descriptions to a certain degree made it possible to compare the estimated values with realities.


## RESUME

Artiklen er et sammendrag af en opgave fra sommeren 1976. Tikopia tilhører Salomon øerne og er beliggende på 168°48' østlig længde og 12°18' sydlig bredde. Øen er velkendt fra professor Raymond Firth's klassiske etnografiske værker. Tikopianerne har igennem lang tid på grund af øens begrænsede areal taget hensyn til forholdet mellem areal og befolkning ved at praktisere fødselskontrol.

Det var vanskeligt at foretage en kvantitativ beskrivelse, da kilderne hertil var få: To luftfotografier fra 1962, en artikel med befolkningsopgørelse på køn og alder i 1929 og 1952 og FAO standard tal til beregning af kalorie- og proteinbehov.

På basis af luftbillederne blev øens totale areal og størrelsen af de enkelte landbrugsregioner beregnet. Inddelingen fremgår af fig. 1. Befolkningens nødvendige kalorie- og proteinforsyning blev beregnet og derudfra et gennemsnitsforbrug. Sammensætningen af dette antoges at være som det fremgår af fig. 5. Herudfra beregnedes de nødvendige mængder for hele 1929 befolkningen. Beregningerne fremgår af tabel 1. Det fremgår heraf, at med den antagne sammensætning af diæten er proteinforsyningen for 1929 næsten stor nok til at dække 1952-behovet. Af fig. 6 fremgår det at diæten synes godt sammensat med hensyn til animalsk protein, hvilket kan forklares ved begrænsede landressourcer og let adgang til havet.

Udfra den nødvendige produktion af fødevarer beregnedes arealet til at dyrke denne mængde. Resultatet var at 0.27 ha/cap. og 0.075 ha/cap./år var nødvendigt (tabel 2). For at skaffe de nødvendige arealer må rotationslængden i kraterområdet ikke overstige 5 år, hvilket er en kort periode og formentlig kun er muligt på grund af en frugtbar jordbund.

For at prøve at beregne værdiers sammenhæng blev de indsat i forskellige bæreevneformler. Alle resultater pegede henimod at Tikopia i 1929 havde en næsten maksimal befolkning, mens befolkningen i 1952 var så stor, at den ikke kunne ernæres på øen uden en forringelse i dyrkningssystemet. Den på øen bosiddende befolkning er senere stabiliseret på ca. 1000 personer, mens omkring 500 arbejder i kokosplantager på andre øer. Den gode overensstemmelse, der er imellem de beregnede værdier og de indtryk der kan fås fra de etnografiske beskrivelser, kunne betyde, at det vil være muligt med disse afgrænsede midler at beregne bæreevne også i andre områder.


## REFERENCES


Agriculture Handbook nr. 8 (1963). Agricultural Research Service, U.S. Department for Agriculture.

Agriculture Handbook nr. 456 (1975). Agricultural Research Service, U.S. Department for Agriculture.

*Barrau, J.* (1958): Subsistence Agriculture in Melanesia. B.P. Bishop Mus. Bull. 219, Honolulu.

*Barrau, J.* (1961): Subsistence Agriculture in Polynesia and Micronesia. B.P. Bishop Mus. Bull. 223, Honolulu.

*Barrau, J.* (1962): Les Plantes alimentaires de l/Océanie, origines, distribution et usages. Marseilles.

*Beguin, H.* (1964): Modèles Géographiques Pour l/Espace Rural Africain. Bruxelles, Akadémie Royale des Sciences d'Outre-Mer.

*Borrie, W.D., Firth, R., Spillius, J.:* The Population of Tikopia, 1929 and 1952. Population Studies, vol. 10. London 1956-57.

*Carneiro, R.L.* (1956): Slash-and-Burn Agriculture: A Closer Look at its Implications for Settlement Patterns. Men and Cultures, 5th Int. Congr. of Anthr. and Ethnol. Sciences.

*Christensen, S.* (1975): Subsistence on Bellona Island. Folia Geographica Danica. Tom. XIII, Copenhagen.

*Clarke, W.C.* (1971): Place and People. An Ecology of a New Guinean Community. Univ. of Calif. Press.

*Conklin, H.C.* (1957): Population-Land Balance under Systems of Tropical Forest Agriculture. Proc. of the Ninth Pacif. Congr. Vol. 7.

Die Zusammensetzung der Lebensmittel, I-III. Wissenschaftliche Verlagsgesellschaft. M.B.H. Stuttgart.

FAO/WHO (1973): Energy and Protein Requirements. Rome.

*Firth, R.* (1936): We, the Tikopia. Allan and Unwin. London.

*Firth, R.* (1939): Primitive Polynesian Economy. Routledge. London.

*Firth, R.* (1959): Social Change in Tikopia. Re-Study of a Polynesian Community after a Generation. Allan and Unwin. London.

*Henshall, J.D.* (1967): Models of Agricultural Activity. In Chorley and Haggett: Models in Geography. Methuen. London.

*Koch, P.H.* (1970): Die Shifting Cultivation und Ihre Luftbildauswertung. Juris Verlag. Zürich.

*Larson, E.H.:* Tikopia Plantation Labour and Company Manament Relations. Oceania, vol. 40. 1969-70.

*Waddell, E.* (1972): The Mound Builders. Univ. of Washington Press.