WORK AND JOURNEY TO WORK IN SUBSISTENCE AGRICULTURE
- a case of cultivation of scattered areas on Rennell Island (Mugaba).

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In subsistence agriculture, area and work are usually the most important production factors. Total cultivation work is shown to be greatly increased, if journeying to work is augmented, as when cultivated areas are scattered. Formulae are devised for the increase of total work caused by transport.

On Rennell Island (Mugaba) the traditional bisettlement-based cultivation strategy is demonstrated to be a rational means to diminish the journey to work problem.

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For a subsistence system proper, carrying capacity for population in a given area is thought to be an important characteristic (S. Christiansen 1976). The carrying capacity is a property attached to the production system (which is not necessarily regarded as static), but of course also influenced upon by the environmental potential.

Under subsistence conditions, the main variable production input is work. Capital is usually very scarce, limiting access to tools, fertilizers, seed material etc. severely. The amount of work employed is thus largely determining output. Usually work is available in sufficient quantity in subsistence agriculture, though certain 'bottle necks' in work supply do occur especially in intensive subsistence agriculture e.g. by transplanting and harvesting in cultivation of irrigated rice.

In the formula for the calculation of carrying capacity for population: $P_{max} = A \frac{y}{c}$ where A is the area considered, y the food yield per area unit and c the food consumption per capita) work is not explicity entered. However, work is determining yields (S. Christiansen 1975), see fig. 1. If the variables are measured commonly in energy units, maximum carrying capacity is found to be achieved before maximum yields are attained, namely where output less work (input) is at maximum.

Hence a revised carrying capacity formula can be written: $P_{max} = A \frac{y-c_w}{c}$, where c_w is the consumption resulting from

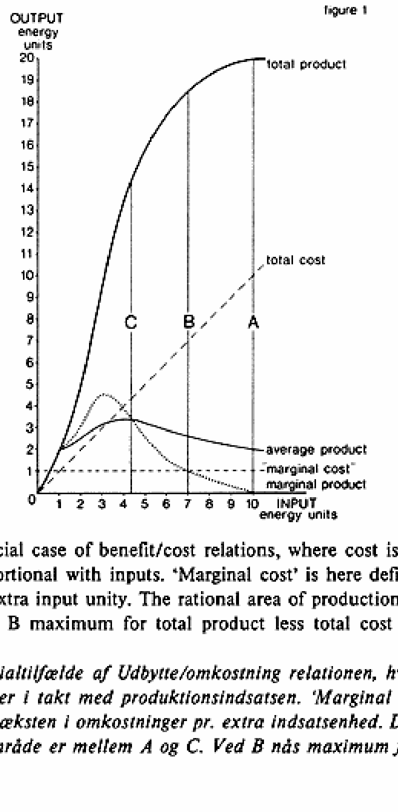

Fig. 1. A special case of benefit/cost relations, where cost is thought to increase proportional with inputs. 'Marginal cost' is here defined as cost increase per extra input unity. The rational area of production is between A and C. At B maximum for total product less total cost is attained.

Fig 1. Et specialtilfælde af Udbytte/omkostning relationen, hvor omkostningerne vokser i takt med produktionsindsatsen. 'Marginal cost' er her opfattet som væksten i omkostninger pr. extra indsatsenhed. Dt rationelle produktionsområde er mellem A og C. Ved B nås maximum for Udbytte-omkostninger.

the work used in production of food. Of course this means that any further increase of work in production diminishes the possible maximum population - here most easily conceived as the maximum biomass in kilogrammes sustainable by the production of the given area. It is noticed that life for the biomass thus assessed is quite drab; there is only energy available to sustain the biomass at rest (disregarding work in subsistence production). Naturally, when calculating the maximum population sustainable by a given system, other norms can be used, but they are of less evident definitions.

At least three limitations to productive work may be mentioned. One is that it takes a considerable amount of time before a subsistence farmer is trained to full efficiency, as he must know every trick of his trade. Another is that he is often under rather heavy climatic stress while working. According to P.O. Fanger (1970) thermal comfort is hardly attainable under conditions with temperatures exceeding 24°C, high humidities and almost no ventilation. This cuts almost daily two hours out of the workday in humid tropical climates for most workers. Usually the subsistence worker depends on daylight for his activities. Including the 'noon black-out' often less than 8 hours are left as a daily maximum period of work. Hours of effective work are, however, often much shorter because of the journey to work and back. Time expenditure in this is felt to warrant a further investigation, especially considering exploitation of scattered areas.

If the efficiency of work is assumed to be uniform, the total effective work can be measured by its duration in hours, H, alone. Total transport hours are given as H_t. The total work is then $H_{total} = H_w + H_t$, where $H_w = A \cdot h_w$. Here A is again the given area, and h_w is the work necessary to cultivate an area unit to the point where it yields its largest net output. Necessary transport time depends on duration of a single journey, h_t, as well as on the number of journeys necessary. This number is at least $\frac{H_w}{h_d - h_t}$, where h_d is daily hours of activity. Thus the total work for the necessary cultivation is:

$$H_{total} = H_w + H_t = A \cdot h_w + \frac{A \cdot h_w}{h_d - h_t} \cdot h_t,$$

$$\text{or } A \cdot h_w \left(1 + \frac{h_t}{h_d - h_t}\right)$$

Slightly transformed this reads

$$H_{total} = A \cdot h_w \left(1 + \frac{1}{(h_d : h_t) - 1}\right)$$

Total work is seen to depend on the work involved in direct cultivation and in transport, which adds a fraction determined by maximum daily working hours in relation to daily time spent on transport in journeying to work.

The addition to total work caused by travelling increase sharply as h_t approaches the normal daily hours of work:

$$\frac{1}{(h_d : h_t) - 1} \rightarrow \infty \text{ for } h_t \rightarrow h_d$$

The extra workhours added to total work by various durations of h_t at constant values of h_d are shown in fig. 2. Even short transport may mean many extra hours. As subsistence cultivators usually travel by foot, and h_d at least seasonally is very short, the incentive to minimize is strong. in table 1 the weights of added travelling is dmonstrated by application to some cases of cultivations. Graphically, the connection found can be expressed in analogue to the 'Hägerstrand time-prism' (T. Hägerstrand 1976), see fig. 3.

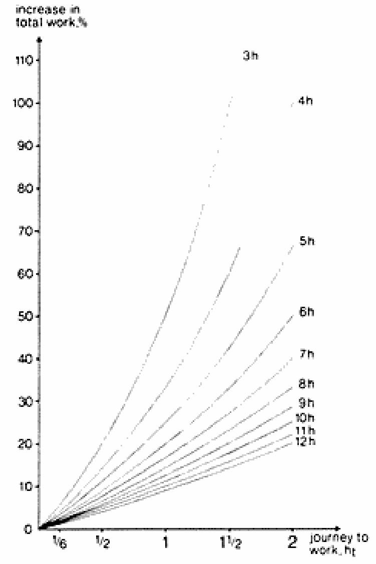

Fig. 2. Increase in total work by increasing journeys to work, h_t, at various lengths of working day, h_d. It is seen that even short journeys influence heavily on the short workdays usually observed in subsistence economies.

Fig. 2. Tilvæksten på totalt arbejde ved voksende tidsforbrug ved arbejde-boligrejser, h_t, ved forskellig længde af arbejdsdagen, h_d. Selv korte rejser forlænger arbejdsomfanget stærkt, særlig ved de korte arbejdsdage, der er almindelige i selvforsyningsøkonomier.

Garden type I, e.g. Bananas - total work 800 hours				
h_t \ h_d	3 hours	6 hours	8 hours	10 hours
0 h	267	133	100	80
1/6 h	+17	+ 4	+ 2	+ 1
1/2 h	+64	+13	+ 7	+ 4
1/1 h	+200	+32	+16	+10
Garden type II, e.g. Taro - total work 1600 hours				
0 h	533	267	200	160
1/6 h	+33	+ 8	+ 4	+ 3
1/2 h	+128	+26	+14	+ 9
1/1 h	+400	+64	+33	+20
Garden type III, e.g. Yams - total work 2400 hours				
0 h	800	400	300	240
1/6 h	+50	+24	+ 7	+ 4
1/2 h	+192	+40	+21	+13
1/1 h	+600	+96	+49	+30

Table 1. Workdays added to total work (incl. journey to work) in 3 different types of gardens by different duration of journeys to work.

Tabel 1. Tilvæksten til det totale arbejde (inkl. rejsetid) ved dyrkningen af tre forskellige typer af haver og ved forskellig rejsetid.

The problem with transport time in subsistence agriculture is aggravated when the area for cultivation (the 'carrying area') lies scattered on several plots:

$$A = A_1 + A_2 + A_3 \ldots\ldots\ldots + A_n \text{ or } A = \sum_{i=1}^{n} A_i.$$

Each of the parts i-n is assumed big enough - or isolated enough - to be worked independently in one or more workdays. If this is the case, the total effective workhours are:

$$H_w = h_w \; A_1 + h_w \cdot A_2 \ldots\ldots + h_w \cdot A_n = h_w \sum_{i=1}^{n} A_i.$$

The corresponding time necessary for traveling is then:

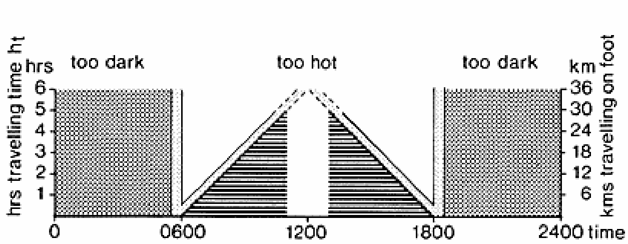

Fig. 3. Influence of journey to work on effective working hours.
The full-drawn lines depict effective working hours (h_w) at variuos duration of travelling, h_t. If 'siesta' is about 2 hours, h_w is only 6 hours. If travel is on foot, the vertical axis is converted into travvelled distance by multiplication with 6 km/h.

Fig. 3. Transporttidens indflydelse på effektive arbejdstimer.
De fuldt optrukne linjer er et mål for effektive arbejdstimer (h_w) for forskellige rejsetider, h_t. Hvis middagspausen er ca. 2 timer er h_w kun 6 timer. Hvis rejsen foretages til fods, kan den lodrette akse udtrykke afstanden ved multiplikation med 6 km pr. time.

$$H_t = \frac{h_w A_1}{h_d - h_{t1}} \cdot h_{t1} + \frac{h_w A_2}{h_d - h_{t2}} \cdot h_{t2} + \ldots + \frac{h_w A_n}{h_d - h_{tn}} \cdot h_{tn} = h_w \sum_{i=1}^{n} \frac{A_i \cdot h_{ti}}{h_d - h_{ti}}$$

where $\frac{h_w \cdot A_i}{h_d - h_{ti}}$ is the ratio between the work per part-area and the daily effective working hours, which equals the number og workdays and hence the necessary journeys to work each of the plots cultivated. If $H_w + H_t$ are added, an expression for the total work is arrived at:

$$H_{total} = H_w + H_t = h_w \sum_{i=1}^{n} A_i + h_w \sum_{i=1}^{n} A_i \text{ or}$$

$$h_w \sum_{i=1}^{n} A_i \left(1 + \frac{h_{ti}}{h_d - h_{ti}} \right)$$

This expression is analogous to the one arrived at earlier; travelling adds an amount of work to the effective hours which is the sum of the product of area and individual travelling time divided by the daily workhours for each of the area plots. Best localization for a settlement is evidently where transport, H_t, is at a minimum, i.e.

$$H_{tmin} = \min. \sum_{i=1}^{n} A_i \frac{h_{ti}}{h_d - h_{ti}}$$

A settlement is, of course, only viable, if there are accessible areas enough within a distance, so that $H_{total} \leqq H_{available}$. Sometimes one or more extra seasonal settlements are an economical solution to the problem of scattered resources, namely if areas can be selected so that total work for cultivation, transport and neccessary housing is less for old and new settlements together than for the original one solely.

Sometimes the scattered, utilizable areas may induce people to move between two ore more settlements. In most cases, however, moves are no doubt seasonal and from regions where areas are utilizable during different periods. Transhumance (or Senne Wirtschaft, seterdrift) in mountainous areas is thus induced by the variance of growth period with altitude. But other reasons than economy of work can also cause a pattern of regular movings. Very often social and religious factors are in fact decisive – contrary to economy of work. But, of course, the 'feasibility limit' is always valid: $H_{total} \leqq H_{available}$.

The effect of extra transport are very pronounced when resources are scattered and travelling is by foot. Even small distances to work can be reflected by responses in the location of settlements.

An interesting example of this effect is seen on the two neighbouring Polynesian islands Bellona (Mungiki) and Rennell (Mugaba) in the Solomon Islands. The islands have almost identical cultures, at least regarding subsistence techniques, but on the small Bellona (10 x 2 km) agricultural areas are largely concentrated in the central part of the island, and only one settlement is used by each inhabitant. On the larger Rennell (85 x 10 km) agricultural areas are rather scattered both on the central plain and on the cliff rims near the coast. Field work carried out 1969 (with Torben Monberg) showed that the 18 households of the village Hatagua in western Rennell used about 180 hectares (of which 46 hectares are annually cultivated) for their sustenance. The cultivated area was composed of more than 200 plots spread within a distance of a little more than 10 kilometres from the central settlement. Traditions were that some 5 satellite settlements were seasonally employed by different people from Hatagua, see fig. 4. A similar pattern was found all over western Rennell where every central village had one or more satellite settlements. Kaangua had the coastal settlement Magautu, Nukuposa'a had Tehatumotu, Tematiga had Na'one, Honga'ubea Te'ana etc.

A calculation demonstrates that this bi-settlement strategy is essentiel for the economical use of land on Rennell. To simplify operations only two strategies have been considered, a one-settlement scheme by which all work starts from Hatagua, and a six-settlement scheme where cultivators change residences within their own properties between Hatagua and a coastal settlement according to tradition. Areas of plots within same distance zone were aggregated. This is justified because Hatagua is placed in a network of radial paths making non-radial tours insignificant. Cultivation work was calculated, estimating one fourth of the area to be annually harvested – which is possibly a rather high ratio, but rea-

Table 2. Total work ($H_w + H_t$)

Distance km	Approx area, hectares cultivated	Approx area, hectares harvested	Mean daily journey to work, hours	Work, hours cultivation	Work, hours extra	Work, hours total
A. Using one settlement only - Hatagua						
0- 1	39	9.8	1/6	9,800	206	10,006
1- 2	43	10.8	1/2	10,800	724	11,524
2- 3	19	4.8	5/6	4,800	557	5,357
3- 4	12	3.0	1 1/6	3,000	510	3,510
4- 5	10	2.5	1 1/2	2,500	578	3,078
5- 6	10	2.5	1 5/6	2,500	535	3,035
6- 7	3	0.8	2 1/6	800	297	1,097
7- 8	25	6.3	2 1/2	6,300	2,860	9,160
8- 9	10	2.5	2 5/6	2,500	1,365	3,865
9-10	10	2.5	3 1/6	2,500	1,638	4,138
10-11	3	0.8	3 1/2	800	622	1,422
A. Total	184	46.3		46,300	9,892	55,892
B. Using six settlements						
Hatagua:						
0 - 1	39	9.8	1/6	9,800	206	10,006
1 - 2	43	10.8	1/2	10,800	724	11,524
2 - 3	19	4.8	5/6	4,800	557	5,324
	101	25.4		25,400	1,487	26,854
Magalea:						
0 - 1	12	3.0	1/6	3,000	63	3,063
1 - 2	11	2.8	1/2	2,800	188	2,988
	23	5.8		5,800	251	6,051
Sanibaga (Tonga):						
0 - 1	10	2.5	1/6	2,500	53	2,553
1 - 2	6	1.5	1/2	1,500	101	1,601
	16	4.0		4,000	154	4,154
Gebia:						
0 - 1	10	2.5	1/6	2,500	53	2,553
Buge:						
0 - 1	7	1.8	1/6	1,800	38	1,838
1 - 2	6	1.5	1/2	1,500	101	1,601
	13	3.3		3,300	139	3,439
Teabagua:						
0 - 1	10	2.5	1/6	2,500	53	2,553
1 - 2	11	2.8	1/2	2,800	188	2,988
	21	5.3		5,300	241	5,541
B. Total	184	46.3		46,300	2,325	48,592
A - B					7,567	

Hatagua village and accessory settlements, 1969.

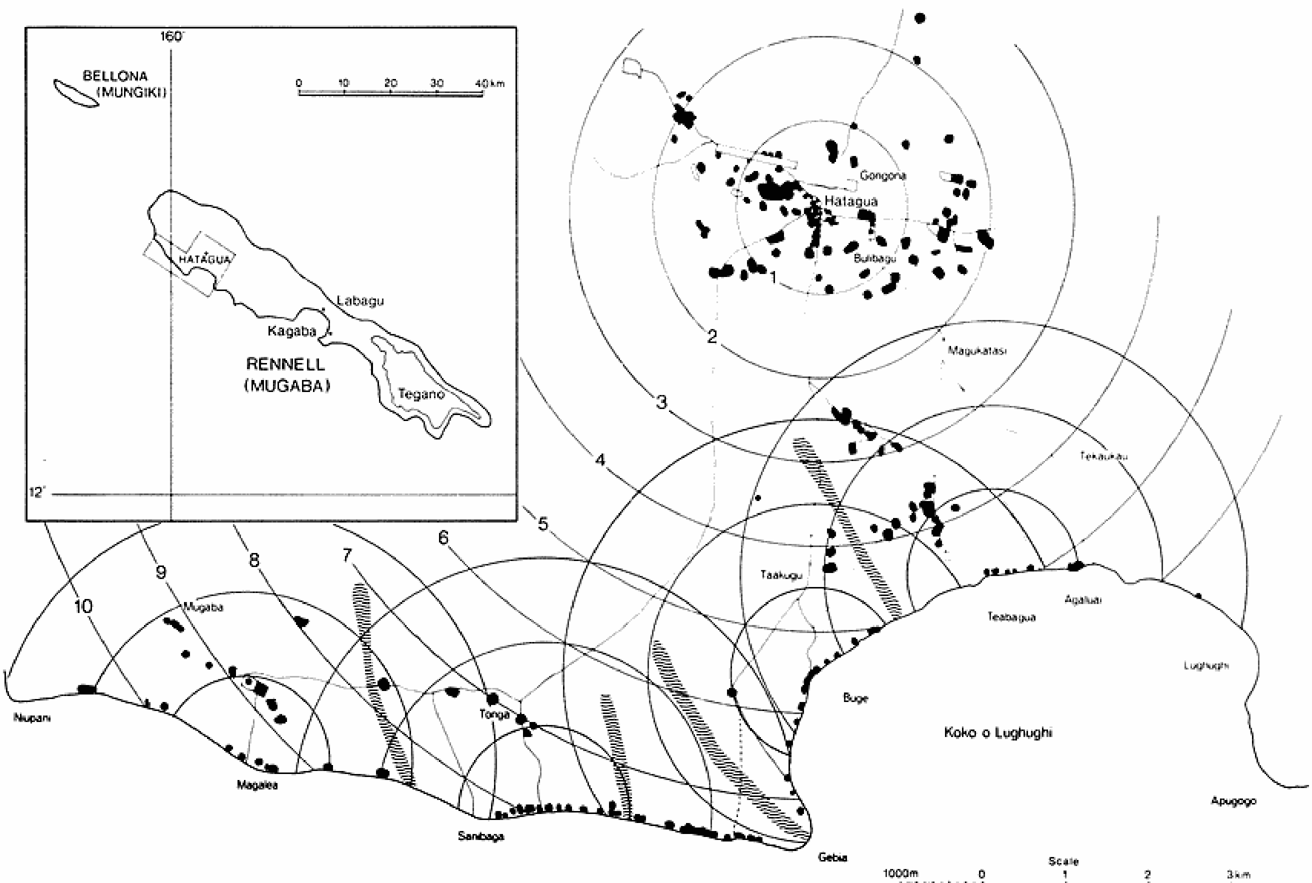

Fig. 4. The area around Hatagua village and Bellona and Rennell islands. Distances (kilometres) from Hatagua and other settlements are shown by circles. Cultivated areas (black) are very scattered; boundaries between lands cultivated from different settlements are shown hatched.

Fig. 4. Arealet omkring Hatagua samt øerne Bellona og Rennell. Afstande (i km) fra Hatagua og andre landsbyer er vist ved cirkler. De dyrkede arealer, markeret med sort, ligger meget spredt. rænserne mellem de arealer, der dyrkes fra forskellige landsbyer, er vist ved skravering.

sonable for the less work-intensive cultivations. The work per hectare was set at 1000 hours per annum; a low figure compared to Bellonese ones (S. Christiansen 1975). However cultivation on Rennell is usually considered less work-intensive than on Bellona. Daily working hours were assumed to be eight, and the extra work caused by journeying to work calculated from the formul previously found. Travelling time was found from the mean distance to each zone and a walking speed of 6 kms per hour.

From the tables A and B (table 2) the resulting total work by using one settlement and by six settlements may be compared. The total amount of work is seen not to supass the capacity of the work force, which i estimated to be arround 90,000 hours per annum (about 45 able adults at each 2000 hours). As calculations were aiming at minimum values, the difference in favour of the six-settlement strategy (more than 7500 workhours per annum) is no doubt an underestimate. As an average house including kitchen usually costs less than 200 workhours (S. Christiansen 1975), the extra costs of housing needed is easily covered by the 'nomadic'strategy. On the well-drained beaches, houses can even be built and kept at smaller expenses than normal. An essential further advantage by the 'migrating subsistence cultivation' is that access to the seasonal fishing is greatly eased. The main conclusion is, however, that the economy of the bisettlement strategy is superior, even if solely agriculture is regarded.

A brief note on terminology may be added. Whittlesey's advise to define 'shifting cultivation' as an agricultural technique resting on bush- or forest fallowing excluding anything on permanency/non-permanency of settling is justified (Whittlesey 1937). The use of the term 'migratory farming' for shifting cultivations is usually unwarranted because a fixed settlement is used. However, it seems useful to distinguish between two types of shifting cultivation: 'stationary shifting cultivation' (with permanent settlement) or 'migratory shifting cultivation' with changing settlement. To sharpen distinctions, Rennellese cultivation, which bears some resemblance to 'transhumance' in animal husbandry, may even be termed 'seasonal migratory shifting cultivation'.

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'.

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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.

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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

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