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PROSPECTS FOR SETTLEMENT IN NORTH-EASTERN NEW GUINEA

BY

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9-47

TABLE OF CONTENTS

	PAGE
Foreword	5
Some Comments by Other Writers on New Guinea's Prospects	9
Location, Major Lineaments, and Population	16
Topographic Contrasts and Influences	19
Mining Prospects	23
Climatic Contrasts	24
Effect of Climate Upon Health and Energy	29
Forests and Grasslands	31
Soil Fertility	38
Experience with Army Farms in New Guinea	45
Area of Cultivable Land	49
Crop Possibilities	51
Availability of Native Labor	60
Transportation Facilities and Needs	63
Location and Design of Houses	66
Suggestions for Proper Clothing	71
Tropical Diseases and their Control in New Guinea	74
Readjustment of Working Schedules Desirable	80
Some Additional Conditions for Successful Settlement in Lowland New Guinea	81
Market Prospects	82
Conclusions	87
Recommendations	92
Appendices (A-E)	97
Illustrations	112

PROSPECTS FOR SETTLEMENT IN NORTHEASTERN NEW GUINEA *

Foreword

Early one morning in March, 1944, our transport plane rose off the steel mat of one of the new Allied air strips near Port Moresby, New Guinea, and headed northwestward toward the cloud-wrapped summits of the Owen Stanley Mountains.* Half an hour later we had climbed to about 8,000 feet and turned due north to slip through a narrow cleft in the range. Beyond lay one of the most exciting panoramas we had ever seen, with a confusion of steep-sided mountain spurs in the foreground, the deeply-scored surface of the plateau of central New Guinea off to our left, and a series of majestic mountain ranges rising wave on wave toward the northern horizon. An incredibly blue sky above and wraith-like swirls of scattered cumulus clouds below us heightened the color contrasts of valley floors and mountain slopes, with their changing patterns of forest, grassland, and native villages and gardens which seemed to be abundant in these highland valleys. Crossing one range after another, with each valley and mountain crest offering new vistas, we finally went into a long, gentle glide toward a wide expanse of grassland on the floor of the Markham valley near Nadzab. This was my introduction to New Guinea.

In the months following I came to know this part of New Guinea much better, both from the ground and from the air. My work took me by air to various parts of the Markham and Ramu valleys, to the plateau between Bena Bena and Mt. Hagen, and to the coastal lowlands between Lae and Dobodura.** Aerial observations were there supplemented with ground traverses by jeep and on foot. There were opportunities at various times during my stay to talk with Australian military personnel and civil government officials

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* This study was completed in 1947 for The Refugee Economic Corporation of New York, to which the author wishes to express grateful acknowledgment for permission to publish his report in this slightly revised form. Thanks also are due The American Geographical Society of New York for permission to reproduce the map (Plate I) and a number of photographs from his article, "Army Farms and Agricultural Development in The Southwest Pacific," which appeared in the July issue of the *Geographical Review*, 1946. (Vol. XXXVI, No. 3, 1946, pp. 420-446.)

** See map, Plate I.

long resident in New Guinea, whom I plied with questions about native life, problems of transport, mining developments and prospects, forest resources, climatic conditions, soil fertility, farming and grazing possibilities, health conditions and hospital facilities, and government plans for postwar reconstruction. In most cases these men spoke about New Guinea's prospects in what seemed to be a reasonable manner, balancing the known assets of the country against its recognized liabilities, and the needs of the natives against the interests of the white man.

Additional information was obtained through conversations with American military personnel, especially medical officers, engineers, weather forecasters, and agricultural specialists in the Quartermaster Corps, and from various reports, letters, memoranda and published material on file at different headquarters. Visits to Australia helped to round out the picture as contacts were made with Australians who had either lived in New Guinea or on other tropical islands north of Australia at one time or another, or traveled extensively there. Since my return to the United States in November, 1945, there has been further opportunity to examine the literature on northeastern New Guinea which, meager and sometimes unreliable though it be, is at least of some assistance in helping us to assess the resources of the region as we now know them and to formulate opinions on the relative desirability of this part of New Guinea as an area for settlement.

We possess insufficient reliable information at the present time to justify a detailed analysis of settlement prospects in New Guinea as a whole. Casual observation, most of it from the air, suggests that the greater part of the island's approximately 312,000 square miles * of surface is either too rough, high, densely forested, swampy, inaccessible, unhealthy, hot and humid, infertile, or thickly populated with natives to permit large-scale settlement. Present estimates of New Guinea's population carrying capacity might have to be revised upward, however, in the event of unexpectedly rich mineral or petroleum discoveries, substantially increased world demand for tropical hardwoods or plantation-grown products, increased population pressure in other countries, tolerance of lower standards of living, or changing land and native policies. Most of New Guinea can not properly be evaluated until its resources are more thoroughly prospected and inventoried, the needs of the na-

* Estimates vary. This one refers only to the main island.

tives more clearly defined, and world economic and political trends better understood than at present.

We may have reached a point, on the other hand, where certain parts of New Guinea should be examined more carefully in relation to the island's future needs and possibilities, and to world-wide patterns and problems of population and land use. The areas that now appear to be worth such consideration, in my opinion, lie in the eastern half of the island, about the head of the Gulf of Papua in the Territory of Papua and in the vicinity of Huon Gulf on the north side of the island in the Mandated Territory of New Guinea. In expressing this opinion, I have some support from a number of scientists, government officials, long-term residents in New Guinea, and others more or less familiar with local conditions. Before turning to an analysis of the prospects in northeastern New Guinea, therefore — the region which I believe holds the greater promise of the two — it is fitting that we present some of the observations and conclusions of these persons.

SOME COMMENTS BY OTHER WRITERS ON NEW GUINEA'S PROSPECTS

New Guinea, like most other parts of the world, has both its boosters and its disparagers. Some visitors, entranced with its snowy peaks, green jungles, emerald lagoons, glistening beaches, and the stone-age culture of some of its natives, see it as a neglected land, a land of immense — even "unlimited" — resources waiting only for outsiders to bring knowledge, energy, and tools to transform it into a great island empire. Soldiers of World War II who slogged and fought their way through some of its swamps and jungles and over its foggy, precipitous mountains, or languished for a year or two at remote military bases, usually and understandably consider it one of the last places in the world where anyone would want to live. The truth seems to lie somewhere between these extremes. New Guinea is a large island with many landscapes and many moods; a land of poverty and wealth, of successes and failures, of significant possibilities and rather severe limitations. One man's opinion, however, is bound to be colored by his personal predilections, and we therefore turn to other specialists for judgments on this debatable land.

Marr [1] writes of the Markham valley in New Guinea that "This tract of country . . . appears from many points of view to be one of the most promising in the Territory of New Guinea (together with the Ramu and Purari valleys) for the grazing of cattle, and the possible development of native agriculture under administrative supervision." He adds: ". . . the Markham and Ramu valleys have a healthy climate suitable for white settlers, a soil of great potential fertility, and a climate suitable for the grazing and fattening of cattle." [2]

Of Australian New Guinea, Roberts [3] writes, "Neither colony . . . (Papua, or Ex-German New Guinea) . . . has developed its production to anything approaching the limit, and the cultures other than copra are clearly in their infancy. The difficulties are lack of capital

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[1] Colin C. Marr: "An Agricultural Survey of the Markham Valley in the Morobe District." *The New Guinea Agricultural Gazette*, Vol. 4, No. 1, January 1938, p. 2.

[2] Marr, *op. cit.*, p. 12.

[3] S. H. Roberts: *Population Problems of the Pacific*. London, 1927, p. 267.

and shipping rather than a shortage of labor, so far as the European is concerned."

Reed [4] regards the cool and relatively dry uplands of New Guinea as "well-adapted, biologically at least, to further white settlement" especially since they are free from malaria. He continues, "At Kaindi . . . a mining community at an altitude of 7,000 feet, European houses are equipped with heating stoves and fireplaces, and blankets are a necessity every night of the year."

Krieger [5] states: "New Guinea's total area of 360,000 square miles of tropical forest, swamps, and high, precipitous mountain chains remains as yet incompletely explored, and its resources are almost entirely undeveloped."

Wood,[6] a prominent Australian economist, contends that, "Much splendid alluvial land of enormous fertility exists along the coasts and river valleys, but the climate is unhealthy in the extreme . . . the island abounds in plants and timbers of a high economic value, but no serious attempt has yet been made to exploit or even to survey the great resources of New Guinea . . . more than 120 varieties of useful timbers are known to exist, of which the dense ulabo which resists the white ant is at present the most important . . . the immensely fertile valleys and plains afford great possibilities for the development of tropical agriculture. By reason of the distribution of good soils at varying elevations, every tropical commercial crop can be grown in the island. Coconuts, rubber, and sisal-hemp are the main plantation industries so far established. Coffee, cotton, vanilla, kapok, cocoa, tapioca, cinnamon, tea and tobacco are all being grown successfully; but their culture has not yet been attempted on a large scale. Sugar-cane, nutmegs, bananas, yams, breadfruit, ginger, and many edible fruits are also widely grown . . . the railway may yet do for New Guinea what it has already done for Central Africa."

Keesing [7] asserts that the agricultural opportunities in New Guinea "far exceed present utilization" and goes on to say that "this applies not only to tropical products but also to those characteristic of temperate areas which, it has been demonstrated, can

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[4] S. W. Reed: "The Making of Modern New Guinea." *Memoirs Amer. Philos. Soc.*, Vol. 18, 1942.

[5] Herbert W. Krieger: "Island Peoples of the Western Pacific, Micronesia and Melanesia." *Smithsonian Institute, War Background Studies*, No. 16, 1943, p. 61.

[6] Gordon L. Wood: *The Pacific Basin*. Oxford, 1941, pp. 82-84.

[7] Keesing: *The South Seas in the Modern World*, p. 37 and p. 330.

be grown on the plateaus and higher slopes." He adds that, "Potatoes and other crops characteristic of a more temperate climate have been tried out very successfully at a high altitude experiment station in New Guinea."

As for the future of the tropics in general, Sinnott,[8] a professor of botany for 30 years and now Director of the Sheffield Scientific School at Yale University, writes, "We shall more and more use the synthetic ability of plants, not simply for foods or for specific industrial materials but for those simple and really basic raw materials like sugar, starch, cellulose and proteins from which the industrial chemist can, in turn, make so much . . . the tropics, with their high temperatures and other favorable conditions for plant growth, will more and more attract the attention of producers for agriculture and industry."

Elkin,[9] a well-known Australian anthropologist, has a less favorable opinion of prospects in New Guinea. He writes: "White development, particularly of the land, has not been pushed to any great lengths, and that for two reasons; government restrictions in the interest of the natives, and a lack of desire or need on the part of many whites to work or venture in these tropical lands." He points out that between the two World Wars, the increase in land used by whites was from 173,272 to 273,000 acres in the Mandated Territory, or about 5,000 acres a year. Almost all of the increase was in coconut plantations (from 168,000 acres to about 261,000) but the area under cacao increased from 974 to about 2,500 acres, and that under coffee from 68 to about 2,700 acres. The total area in use, however, involved the energies of less than 600 agricultural settlers.

Continuing, Elkin[10] says, "Several factors have contributed to what may seem slow development. The Administrations have exercised restraint in alienating land from the natives' own use, for their interest has been regarded as primary in this regard. But even so, much more land has been available for non-native use than has been utilized . . . in the Mandated Territory, up to 30th June, 1939, 657,199 acres of land had been granted to non-natives for agricultural purposes but only 40 per cent of it is in use. The reasons may be found in the uncertainty of obtaining sufficient

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[8] Edmund W. Sinnott: "Plants Hold the Basic Patents," *Serving Through Science*, U. S. Rubber Co., 1945.

[9] A. P. Elkin: *Wanted — A Charter for the Native Peoples of the Southwest Pacific*. Austr. Publ. Co. Pty. Ltd., Sydney, 1943, p. 62 and p. 29.

[10] Elkin, *op. cit.*, p. 29.

indentured or casual labor, the uncertainty of finding satisfactory markets, the slow initial return on tropical crops, and the unattractiveness of a tropical island climate to Australians, who, in any case, are not crowded out of their own country by over-population . . . the Pacific Islands Year Book, while stating that most of the Mandated Territory is capable of cultivation under tropical staples, warns that it is not a poor man's country; some capital is necessary, at least £1,000."

Elkin[11] further remarks: "Increased development of the Territories by Indentured native labour is out of the question . . . the policy of establishing returned soldiers in a native territory, Papua, was tried out after the last war. It was an ignominious failure, and Papua has only recently rid itself of the debt foisted on it by the Australian Government through that failure. It will fail again, because of labour difficulties, because the soldiers are most unlikely to have had any experience in tropical agriculture, and because few will wait the seven years or so which must pass before a return from a tropical crop can be expected. . . . There may be some reasonably large areas of suitable land which the natives themselves will not use for generations to come . . . (but) . . . while much of New Guinea is not thickly populated, much of the land is of poor quality . . . it may therefore be, that as the native standard of living rises, good land not now used will be needed by various native groups . . . we must beware of alienating any more of their land, even on long leases. It is difficult to resume for natives land which has been in the hands of whites."

Of the interior highlands, Elkin[12] writes: "Some people in Australia and abroad have gathered the impression from explorers' reports that the highlands of the interior of New Guinea (in the Mandated Territory) present a great opportunity for white settlement in a pleasant climate, with, of course, native labour available. . . . According to the District Officers who have explored the area from its eastern extremity, west of the Wau and Bulolo goldfields, to the Dutch border, much of it is extremely mountainous and too rough for white settlement. But there are areas which may be suitable for tea and other products . . . these desirable regions are thickly populated. . . . Assistant District Officer J. L. Taylor, estimated a few years ago that there were 200,000 persons living in

[11] Elkin, *op. cit.*, pp. 30-34.
[12] Elkin, *op. cit.*, pp. 35-36.

the region between Mt. Kratke and Mt. Hagen alone, and census work is showing that this was not an excessive estimation. . . . To Mr. J. L. Taylor the future of the interior highlands lies first of all in native development; the natives will grow quinine, coffee, soya beans and European vegetables; they will also raise pigs, at which they are already specialists, to be cured at a Government co-operative bacon factory. In the second place, after this step has been well taken (and only then, we should add), there will be development by Europeans who would grow the same products and also raise some cattle, but only in a small way . . . it is doubtful whether it would be economically possible for Europeans to develop the area. It is 100 miles from the coast, and the only means of transport for a long time to come is the aeroplane, and this is expensive. Native labour is not available without interfering disastrously with the native's own farming activities. There is practically no local timber for building purposes, and the area of apparently useful farming land is only about 10,000 square miles, and this already carries a fairly dense population."

Professor Douglas H. K. Lee,[18] an Australian physiologist who for some years has studied the reactions of men and animals in arid tropical and humid tropical climates, writes as follows about prospects for settlement in New Guinea: ". . . two . . . places struck me as giving a very direct lie to popular conceptions of steaming jungles and malarial swamps. The first was a series of open grassy terraces going from sea-level to 1,000 feet or more along the eastern coast of the Huon peninsula, from Fortification Point to the Gneisenau Gorge. Whether the soil (coral detritus) would support grazing or agriculture I do not know, but the climate was delightful. . . . Moresby you can have—it is just like a bad piece of Carpentaria, owing to the local peculiarities which deprive it of rainfall. Buna (Dobodura) and Lae are flat, uninteresting and oppressive places. Something could be made of Finschhafen, I believe. The Markham Valley, I agree, has great possibilities, provided that malaria control is kept up. The whole of the Fly delta strikes me as very unpromising; in fact, it is my impression that the Dutch get by far the worst part of New Guinea.

"The difficulty I see about developing New Guinea is two-fold. First, it requires considerable manual labour, and that is what the white man is trying to avoid more and more even in temperate

[18] Written communication, October, 1946.

climates, as he becomes the victim of his machines. He is even less likely to undertake it when the climate conspires to reduce his initiative. He would require therefore, either to depend upon coloured labour . . . or to import machines. There is not much reserve of native labour if village life is safeguarded. . . . Machines are costly and can be employed only if the Islands are subsidised by the mainland or if the Islands are subjected to financial exploitation. The first may be done on the score of defence . . . the second process . . . will wreck Island economy for all time.

"I sound pessimistic! Rather let me say I am not optimistic. Our tropical regions can be inhabited and developed by white men, but only if they play the game by biological rules . . . tropical development calls for a better man, a man who has a purpose and is prepared to work for that purpose. More particularly, and I cannot stress this too much, it calls for a woman who shares that purpose and is equally determined to work for it . . . if we . . . (Australians) . . . do not develop the tropical islands under our jurisdiction in the next fifty years . . . the non-Caucasian will and not for us. . . ."

Here we have a number of opinions bearing on the habitability and future prospects of New Guinea, with anthropologists, economists, Government officials, agricultural specialists and authorities on population problems expressing divergent views, though dealing with a common denominator—New Guinea. Elkin rightly calls attention to the fact that the more desirable plateau valleys are already well-populated, to the need for a reserve of land for natives in the future, the failures of soldier settlement schemes in Papua, the rather unfavorable economic position of plantations prior to World War I, the difficulties of transportation, and the improbability of Australians colonizing a tropical outpost in significant numbers when there is so much yet to be done in the way of development in Australia. Certain questions may be raised, however, concerning his arguments. Could the cool highlands, despite their rather large native population, provide a number of small, attractively and conveniently located sites for recreational facilities and rest camps for the occasional use of settlers colonizing unoccupied parts of the lowlands, without injury to native economy and society? Are there any parts of these lowlands suitable for agricultural settlement by white people, and if so are they lands that the natives will be unable or unlikely to use at any time in the predictable future? Does the

failure of admittedly ill-planned and poorly-equipped Australian soldier settlement in Papua after World War I prove that further white settlement is foredoomed in Papua or other parts of New Guinea? Does the rather doubtful economic position of plantations before the recent war prove that plantations have little or no future in New Guinea, considering that these pre-war plantations put nearly all their eggs in the copra basket instead of diversified plantation products such as tea, coffee, cacao, sisal, sea island cotton, ginger and other spices, tobacco, abaca, tung trees, and derris root? Is it essential or desirable that Australia be the only source for migrants to New Guinea? If not, are there other countries that might willingly provide settlers suitable for such colonization, (and acceptable to Australia), and at the same time contribute funds sufficient to improve transportation facilities, build adequate houses, provide social amenities, obtain competent advisers, establish experimental stations, and guarantee the settlers a reasonable living until they can "get on their own feet"?

These and other questions are considered in this study. I have been unable to discover in the available literature on New Guinea any really detailed description and careful consideration of the possibilities for settlement in the specific area on which attention is here focussed: the Markham and Upper Ramu valleys of northeastern New Guinea and the plateau valleys and mountain slopes bordering this region on the southwest.

In our approach to the problem of settlement opportunities in northeastern New Guinea it is imperative that we recognize not only the differing characteristics of the various sub-regions, but also their relations to each other and to the area as a whole. Each is believed capable of supplying something of vital import, without which group settlement could hardly succeed. The nature and relative importance of these potential contributions would obviously vary. The plateau valleys, for example, might supply recreational facilities and rest areas in a cool climate (involving perhaps a few hundred acres of land for recreational use as well as a limited number of small, intensively cultivated farms) and, perhaps eventually, sites for reservoirs and hydroelectric stations.

The steeper mountain slopes, although they should for the most part remain in forest to safeguard the plains from floods and retard soil erosion, might at the same time provide timber for export or for local construction, and other forest products. Native labor,

though difficult to obtain in the lowlands, could probably be made available in sufficient quantity for necessary road building and rest camp construction on the plateau. The economy of the whole region would have to be thoroughly integrated, and sufficiently diversified to insure a wide variety of products for export, and thus help to relieve New Guinea from its present overwhelming dependence on gold and copra. The fullest development of the island's resources (if that be considered a worthy goal toward which to work) will require consideration of *both* native and white interests, and pooling of their knowledge, equipment, and energies to the advantage of both.

LOCATION, MAJOR LINEAMENTS AND POPULATION

New Guinea is the second largest island in the world. It is a little more than one-third as large as Greenland, and larger than either Borneo or Madagascar. Lying just north of Australia in the South Pacific Ocean, New Guinea extends from the equator to about 11 degrees south latitude and from 130 to 151 degrees east longitude. Its maximum length measured in a northwest to southeast direction is about 1,500 miles and its greatest width, through the center of the island, is close to 500 miles. The area of New Guinea Proper is about 312,000 square miles, or about 16 per cent larger than the state of Texas. Its shape may be likened to that of a roosting bird, with the head and neck stretched out westward toward Borneo and the tail curving gracefully southeastward toward New Zealand. Several large, shallow, bodies of water indent the coastline, the most notable being Geelvink Bay, Astrolabe Bay, Huon Gulf, Collingwood Bay, Goodenough Bay and Milne Bay on the north coast, and MacCluer Gulf, Fak Fak Bay and the Gulf of Papua on the south side of the island.

The surface of the island is dominated by a massive mountain system that extends uninterruptedly from one end of the island to the other and occupies a more or less central position with respect to the north and south coasts. The highest peak, Mt. Wilhelmina in Netherlands New Guinea, is about 16,700 feet high and together with several other high peaks in the immediate vicinity bears a crown of ice and snow throughout the year. At least a dozen peaks on the island rise over 15,000 feet above sea level, and there are literally hundreds that stand over 10,000 feet. Most of the moun-

tain country is extremely rugged, with steep slopes and narrow divides being the rule rather than the exception. Swampy plains prevail over much of the land surface north and south of the main mountain chain, the remainder consisting of outlying mountain ranges, foothills, dissected plateau remnants and proportionately small fragments of well-drained valley floor, coastal plain, and marine terrace.

Dense, tropical rainforest covers most of the lowlands of New Guinea, notable exceptions being an open, savanna-type forest in the south central part of the island (Digoel plains); scattered grasslands on parts of the coastal plains and in some interior valleys where centuries of clearing and burning by the native inhabitants have restricted forest growth; mangrove swamps near the mouths of large rivers; and plantations — mainly coconut trees — where European peoples have obtained a toehold along parts of the coast. Stands of pine forest frequently appear at intermediate altitudes (3,000-7,000 feet) while the higher elevations are characterized by mossy forest, high moors, alpine meadows, or rock and ice.

As might be expected in a region the size of New Guinea, with such wide variations in elevation, exposure, and declivity of slope within relatively short distances, climates and soils show remarkable variation from one part of the island to another. There are hundreds of soil types, and the climates range from "humid tropical" to "tundra," (Arctic), with perhaps a dozen intermediate types represented. Generalizations on climate and soil and their influence on plant and animal life that might be meaningful when applied to other parts of the tropics where uniformity of surface is more marked, such as considerable portions of the Amazon Basin, the Brazilian Plateau, or northern Australia, are apt to be misleading when applied to New Guinea, which is more appropriately likened to Puerto Rico, Java, Luzon and Hawaii in its regional diversity.

The rivers of New Guinea deserve at least passing mention. The Sepik, the Fly, the Purari, the Mamberamo, the Ramu, and the Idenburg might, if they flowed through the hearts of Europe, North Africa, China, South America, or North America, be almost as famous and useful to mankind as the Rhine, Nile, Yangtse, Amazon, or Mississippi. They are mighty rivers in their own right: hundreds of miles long; almost as wide and deep over long distances as their more illustrious counterparts; navigable far inland (steam

launches can penetrate over 500 miles up the Fly River, 300 miles up the Sepik and 150 miles up the Purari); and possessed of an enormous volume of water. It is somewhat ironic that Australia, a country of generally deficient rainfall and stream flow, should control the destiny of half an island less than 100 miles away where enough fresh water flows into the sea annually to irrigate much of the desert country in Australia, if it could only be transported there. (Due to unprecedented drought, scarcely any wheat was harvested in Queensland in 1947. Some wheat farmers sold their artesian water to nearby towns in an effort to survive the calamity. Yet in nearby New Guinea water was a surplus commodity.) Australia's Murray River, sometimes called the "Nile of Australia," is hardly more impressive at any particular point than the Iowa River or the Connecticut, and in volume and width is smaller than any of the rivers mentioned above.

The western half of New Guinea is a political subdivision of the Netherlands East Indies, while the eastern half is Australian territory. The eastern half is further subdivided into the Territory of Papua and the Mandated Territory of New Guinea, though the administrative distinctions between the two territories are becoming increasingly obscure.

No accurate census of the population of New Guinea has yet been taken. It seems likely, however, that the native population of New Guinea Proper does not exceed 1,000,000, while the white population of the island averages less than 5,000. Estimates of population density for the island as a whole are of little significance, because of the wide variation from one valley to the next, from one part of the coast to another, or from the coast to the interior. There are adjoining valleys in the interior where the population density ranges from 0 persons per square mile (uninhabited) to more than one hundred per square mile. It has already been pointed out that there are over 200,000 natives on the plateau of central New Guinea between Mt. Kratke and Mt. Hagen, while there appear to be less than 5,000 natives in an area of comparable size in the Markham and Ramu valleys bordering the plateau on the north.

The Mandated Territory of New Guinea, or, as it is sometimes referred to, Northeastern New Guinea, covers an area larger than that of Great Britain, although the Mandate includes, in addition to roughly 25 per cent of the mainland of New Guinea, the Bismarck Archipelago, the Northern Solomons, and smaller neighboring

island groups. The total population of the Mandate in 1942 was over 600,000 and of this number only about 4,500 were white people.

TOPOGRAPHIC CONTRASTS AND INFLUENCES

A remarkable corridor is one of the chief topographic features of northeastern New Guinea. It is drained by the Markham and Ramu river systems and lies between Huon Gulf and the swampy lowlands of the Sepik river basin.* Essentially tectonic in origin, it appears to be the result of major dislocations in the earth's crust along a northwest-southeast axis for a distance of several hundred miles. This huge cleft in the mountain ranges is in truth one of the most spectacular, if least known, topographic features of its kind in the world, rivalling in some respects the great rift valleys of East Africa and far surpassing in grandeur the much publicized but comparatively puny San Andreas Rift in California. For 300 miles it forms a deep, nearly straight trough flanked by towering mountain ranges, the floor at no point standing more than 1,500 feet above sea level. The floor rises gradually from either end to an almost imperceptible divide a few miles west of the native village of Kaiapit. Southeast of the port of Lae the rift continues for several hundred miles as a depression in the sea floor between New Guinea and New Britain.

Along the Ramu river and throughout the valley of the Markham the floor of the trough is almost flat in cross section. A distinct break in slope occurs along both sides where the plains give way to steep mountain slopes. The floor averages about 8-10 miles in width over a distance of some 200 miles; it is approximately three miles wide at its narrowest point between Gusap and Kaiapit, but flares slightly toward the lower Ramu and lower Markham rivers, where it attains a width of over 12 miles.

On the northeast side of the corridor the mountains rise abruptly to a maximum elevation of 13,500 feet near Kaiapit, and there are many peaks standing well over 10,000 feet above sea level in the Rawlinson, Saruwaged and Finisterre ranges. The southwestern limits of the corridor are marked by the Kratke, Kuper, Hersog (Bnangs), Bismarck, and Schrader mountains, the tops of which stand for the most part above 7,000 feet, and near Bundi rise to 15,400 feet in Mt. Wilhelm, which now and then despite its proximity to the equator (7° S.), is capped with gleaming snow.

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* See map, Plate II.

Viewed from an airplane approaching Lae from the southeast, the lower (eastern) end of the Markham valley with its dull-green transverse band of rainforest and swampforest resembles a threshold, beyond which the light-green, grassy plains, dotted here and there with clumps of trees, extend as far as the eye can see toward the northwest. To the right and left of the observer the massive, lofty mountains rise in two great, roughly-parallel chains, their lower slopes clothed with a combination of grass and forest and their upper slopes (above 3,000 feet) with rainforest, stands of pine, and mossy forest. At the left, near the southern edge of the alluvial plain, is the mouth of the Markham river, broad and sluggish and fringed with mangroves. At the right lies Lae, chief port and capital of the Mandated Territory of New Guinea, though in normal times it is little more than a coastal village containing a few dispersed government buildings, warehouses, a hotel, several general stores and private houses whose red-or-white painted, galvanized-iron roofs contrast sharply with the green of the surrounding coconut plantations and rainforest.

The Markham river is about 100 miles long and flows generally southeastward from its source in the mountains north of Kaiapit, hugging the foothills along the southwestern side of the valley throughout most of its course. The main river and its numerous tributaries are surface streams, yet most of them lack well-defined watercourses in the valley proper and are subject to a good deal of lateral shifting within the limits of their normally wide beds. Most of them are "braided" streams, each one having characteristic diverging and converging channels, occasionally blending to form a single, swift-flowing river of considerable volume and width in wet weather. Nearly all the river beds are choked with gravel, and to a lesser extent with sand. In spells of dry weather the Markham and its tributaries are shallow streams with little volume. Tropical downpours on the ranges bordering the valley, however, frequently bring about a rapid rise in the water level of the streams below, which after very heavy and prolonged rains may become raging torrents and flood limited parts of the plain adjacent. As a rule the fall in water level after such rains is also rather rapid. Only in the vicinity of the main channel or channels and in a few small, scattered, undrained depressions on the margins of the interfluves does water stand for any appreciable length of time after

the rains have stopped.* It is essential, however, that the capricious habits of these streams be thoroughly understood prior to any agricultural development of the area, and that land selected for cultivation be safe from the harmful effects of inundation. The peculiarities of each river and river bed should be carefully examined. The beds vary, for example, from less than 20 feet in width for some of the smaller tributaries to nearly three miles in the case of portions of the Manyang and Markham rivers. All of the stream beds lie within 15 or 20 feet of the level of the surrounding plains.

The normal depth of the main channel in all the major streams of this area probably does not exceed three feet, except in the lower reaches of the Ramu river, which is navigable by coastal vessels of small size and shallow draft for a distance of about 100 miles from the river mouth. The current in the principal streams in places and at times exceeds eight miles per hour, and probably averages three or four. The slope of the bed of the Markham river is about 15 feet to the mile between Lae and Gusap. Although the plains flanking the river appear flat when viewed from the air, parts of them are undulating, especially in the area a few miles west of Nadzab.

The so-called "plateau of New Guinea," which lies southwest of the Markham-Ramu trough, is an intricately dissected erosion surface that bears little resemblance to the tabular features commonly classed as plateaus in some parts of the world. From an airplane flying several thousand feet over the Markham valley one sees a succession of rugged, lofty mountain ranges off to the south, with only a rough approximation of parallelism in their longitudinal axes and a mere suggestion of accordance in summit elevations. Separating these ranges are long, deep valleys, most of which have V-shaped cross sections. The streams responsible, at least in part, for their sculpture often occupy narrow gorges at the bottom. Some valleys, however, are broad, open, and characterized by U-shaped cross sections. Gently sloping terraces, alluvial fans or flood plains have been built up on these wider valley floors by successive accumulations of detritus washed from the ranges adjacent. None of these interior valleys compares with the great Markham-Ramu trough either in length or width, although the Waghi valley between Chimbu and Mt. Hagen is about 60 miles long and averages three to five

* The Markham valley as a whole is well-drained, and there are few swamps. The largest of these swamps is about six miles east of the Leron river and is only about one-half mile in diameter.

miles in width. The plateau valleys with which we here are concerned lie between Wau and Mt. Hagen — a total distance of about 200 miles. Their floors lie at elevations ranging from 3,000 to 4,000 feet in the Wau area to 6,000 feet or more near Mt. Hagen. Among these valleys should be mentioned the Wau-Bulolo, the Watut, the Aiyura-Kainantu, the upper Purari, and the Waghi. Rising high above the valley floors, which themselves stand well above sea level, are the majestic ranges that reach elevations of 10,000 feet near Wau, 12,000 feet near Tsili Tsili, over 15,000 feet near Chimbu, and 12,000 to 13,000 feet in the neighborhood of Mt. Hagen.

The land forms of this whole region exert a profound influence on local climates, soils and plant growth, and in consequence both restrict native economy and the prospects for closer settlement and more intensive land use in some places, while favoring them in others. The steeper mountain slopes, for example, are nearly everywhere unsuited for cultivation, except in strictly limited parts of the narrow foothill zone. Their potential use is likely to be confined to forestry, mining, watershed protection and power production, although in places where the altitude is not too great, where the soil is suitable, and the slopes are not too steep, tree crops such as coffee might be grown successfully if cover crops are used to protect the surface from soil erosion. Where the altitude is greater than 8,000 feet the climate is probably unsuitable for any type of agriculture or horticulture, and forestry and perhaps some grazing in the higher valleys or alpine meadows present the most likely alternatives.

On the floors of the main valleys below 8,000 feet elevation, much, though by no means all, of the land is suitable for farming. Some is already used by natives for this purpose. In the Markham and Ramu valleys, however, there are great tracts of land that give every indication of being permanently idle or used only occasionally for hunting wild game, that may prove capable of producing sustained and satisfactory yields of a wide variety of crops, or swards suitable for the grazing of livestock. Variations in slope, altitude and exposure to the monsoon within the larger valleys will narrow or broaden the range of economic opportunities as they influence drainage, soil moisture, depth of soil, temperature, humidity, intensity and duration of sunlight, seasonal distribution of rainfall or the use of farm machinery.

MINING PROSPECTS

New Guinea has been described as "rich in mineral deposits,"[14] but this is guesswork if exploitable ores are implied, the extent and value of such deposits being still largely unknown. Too little is known of the detailed structural geology and petrography of the Mandated Territory of New Guinea in view of the extent of the territory and the known diversity of its rocks and structures. Except in the vicinity of the gold fields near Wau and Bulolo, and in the Aitape region on the northwest coast where oil prospecting has recently been under way, little systematic geological work has been done. A few notes from explorers' and prospectors' journals, and brief general reports of government patrols, are the only sources of information yet available for most of the region.

Gold is the only mineral known to exist in commercial quantities in the Mandate, and the gold fields at Wau and Bulolo have yielded as high as $10,000,000 worth of gold in a year, mostly from large-scale dredging operations. The Leahy brothers, who played an important part in exploring the interior and who so far have been the only Australians allowed to mine gold in the Waghi Valley, have taken some gold from the streams near Mt. Hagen. Australians who have lived for many years in the Mandate sometimes remark that "there is gold in every stream bed in New Guinea." While this is an exaggeration, it is quite likely that important discoveries of this metal will be made in the future in parts of the Mandate not yet fully explored or prospected. In the southeastern part of the island gold, copper, silver, lead, zinc, osmiridium and graphite deposits have already been worked. There is a new gold concession in the interior of Dutch New Guinea. Coal is known to occur in several places,[15] and brown coal has been picked up in stream beds near the mouth of the Markham river.[16] Petroleum in commercial quantities has recently been found in Dutch New Guinea, and oil-deficient Australia has been encouraging geological surveys and test-drilling in the Aitape region on the northwest coast of the Mandate. Oil seeps are common in this area and promising anti-

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[14] Wood, *op. cit.*, p. 83.

[15] H. Foster Bain ("Ores and Industry in the Far East," Council on Foreign Relations, New York, 1933, p. 74) quotes E. A. Douglas ("Coal Resources of the World," Vol. I, pp. 102-105) to the effect that New Guinea has "very large" coal resources. There is, however, no mention of the size of the coal deposits, the quality of the coal, or its specific location.

[16] Marr, *op. cit.*, p. 5.

clinical structures have been found. Petroleum exploration, interrupted by the war, has since been resumed.

While we are not now justified in *predicting* rich mining developments in the Mandate in the future, offering additional opportunities for settlers, there is some likelihood that valuable mineral deposits do exist. On a trip to Mt. Hagen in June, 1944, for example, our party was shown some quartz crystals which had been brought to the Australian officer at the government outpost by natives, who said they found "many of them" in the hills nearby. One of our group, an electrical engineer, was greatly interested in them, in view of the importance of good quality quartz crystal in the rapidly expanding electronics industry. The crystals we saw, according to this expert, were not large enough to be of commercial value, but their existence at least suggests the *possibility* of finding commercial deposits of quartz crystal on the plateau.

A final word on general features seems desirable. Northeast of Kaiapit the mountains appear to consist for the most part of conglomerates, soft, friable sandstone, and mudstones with fossil shells, for pebbles of these types are common in the Leron river bed.[17] The mountains farther east on the south side of the Huon Peninsula appear to be largely composed of diorite, the stream beds of that area containing a high percentage of waterworn diorite pebbles. There seems to be little evidence of metamorphic rocks in this particular region. Limestone outcrops are visible at several points on the south side of the Markham valley, and there appears to be a mountain composed mainly of this rock (or marble??) on the plateau between Bena Bena and Chimbu. Explorers, seeing its gleaming, white cliffs from a distance, have at times mistaken the limestone outcrops for snow fields.

CLIMATIC CONTRASTS

No accurate, detailed information on the climates of this part of New Guinea is available at the present time.[18] Records of temperature and rainfall have been kept at a few outposts, but they are widely scattered and the records cover only short periods. They

[17] Marr, *op. cit.*, p. 5.

[18] See, however, *The Official Handbook of the Territory of New Guinea*, Govt. Printer, Canberra (Australia), 1937, and *Results of Rainfall Observations Made in Papua, Mandated Territory of New Guinea, Solomon Islands, New Hebrides*, etc. Bureau of Meteorology, Melbourne, 1940, for such information as is now available.

are of little help in gaining a reliable picture of the role of local climates in respect to land use. Local differences in elevation, slope, and exposure to the monsoons are, however, undoubtedly reflected in variations in temperature and annual and seasonal distribution of rainfall, in the frequency, intensity and duration of "dry" spells, in the availability of soil moisture, and in the rate of run-off, volume of stream flow, and character of the vegetation from place to place.

While a systematic and detailed account of local weather and climate can not yet be given, it is possible to describe briefly some of the broad climatic features of those major valleys where the prospects for settlement would seem to be worth consideration. If settlement begins by dependence upon a few tropical staples, an enterprising policy will at once provide for experiment with other staples that will help diversify production for local needs. The following paragraphs disclose where beginnings can be made. Enough is known, in my judgment, to justify such beginnings. We are not entirely in the dark as to attractive possibilities if the scale of operations is kept small enough to be readily manageable and experimental for a time. Success with a few specific crops may well be within reach and practicable.

We now proceed to illustrate these generalizations by reference to particular valleys. The lower (eastern and western) extremities of the Markham and Ramu valleys have a different climate from that prevailing in the middle and upper (interior) parts of these river valleys. The eastern end of the corridor is fully exposed to the southeast monsoon (June to October) and gets the greater part of its rain at this season, while the rest of the corridor is relatively "dry." During the northwest monsoon (November to May) the eastern part is relatively "dry," while the rest is under the influence of northwesterly winds, with the full impact of the monsoon felt in the lower Ramu valley. The dividing line between the two areas of contrasting monsoons appears to lie somewhere near the Leron River, about 30 miles west of Lae.

Illustrating the marked differences in rainfall from one part of the area to another, resulting chiefly from local variations in altitude, distance from the sea, and exposure to the monsoons, the rainfall over a five-year period at Kaiapit (70 miles west of Lae with an altitude of 900 feet), has been found to average nearly 100 inches a year, while at Sangan Experiment Station (55 miles west of Lae

and near the center of the valley at about 700 feet) the annual rainfall has been reported as approximately 70 inches.[19] In both cases practically the entire rainfall came during the northwest monsoon. At Lae, close to sea level but exposed to the southeast monsoon, the rainfall is considerably greater than that at either Kaiapit or Saugan (about 200 inches per annum). It is certain, furthermore, that the total annual rainfall not only varies significantly from one part of the region to another, but that it also fluctuates substantially from one year or period of years to another. Most rainfall in northeastern New Guinea appears to be correlated with the convergence of air masses of different temperature, moisture content, and energy potential along the intertropical front, which shifts northward and southward in response to the changing altitude of the sun, as well as with the lifting of the monsoonal air flow over mountain barriers. The specific patterns of air mass convergence change from one season to another and from one year to another, but as yet there seems to be no adequate explanation of the ultimate cause of this change or any evidence as to whether the patterns are repeated over a cycle or period of years. Presumably, however, the convergence is related to the interchanges of air between lower and higher latitudes, to variations in insolation and to differential surface heating, pressure fields and topographic influences. Whatever the yearly variations may be or the cause of them, however, the fact remains that the Markham and Ramu valleys, together with the adjacent mountain slopes and plateau valleys, are well-watered. Drought is unknown, and the occasional short dry spells are a help, rather than a hindrance, from the agricultural standpoint.

Temperatures on the floors of the Markham and Ramu valleys are usually high (80° — 90° F.) during the middle of the day, but moderate (65° — 75° F.) at night, with an average annual shade temperature for the corridor as a whole probably in the low 80's. Temperatures slightly over 90 degrees * are frequently recorded at lower elevations inland in mid-afternoon during the "dry" season; the absolute maximum is probably in the neighborhood of 100 degrees. Early morning temperatures at lower elevations in the Markham valley are usually in the low 70's. The humidity is generally fairly high, especially in the coastal region near Lae, resulting in

[19] Marr, *op. cit.*, pp. 7-8.

* All temperatures given here are Fahrenheit.

"sensible" temperatures that probably approximate those of the Gulf Coast of the United States during our summer months.** While many of our troops in New Guinea during the war performed heavy physical tasks through the heat of the day, it was probably by overdraft on their energies, and an intelligent peacetime work schedule should provide for the performance of the heavier tasks in the early morning or late afternoon. At Gusap, which lies well inland and about 1,200 feet above sea level, nights are considerably cooler than those lower down the Markham or Ramu valleys due to cool air drainage from the mountains adjacent, and the midday heat is tempered somewhat by breezes and lower humidity. During the period from March, 1944 to July, 1944, I had no difficulty in sleeping at night anywhere in this region. To be sure our base camp was on the northern edge of the valley near Nadzab, about 200 feet above the valley floor where strong breezes were common in the afternoon, while cool air drained down at night into the valley from the mountain slopes above. In the early morning a blanket was often welcome, especially if one had already spent several months in the tropical lowlands and had become sensitive to slight changes in temperature.

A breeze is always of great physiologic value in the lower elevations in the humid tropics. Houses are much cooler if they are built on the slopes above the valley floors and sited as well as constructed in such a way that they get the most benefit from air movements. Electric fans also help to make room atmospheres quite tolerable, even during the noon-day heat. Locating houses on the hill slopes even a hundred feet above the valley floor and cleaning out the surrounding undergrowth also substantially reduces the mosquito nuisance.

The climate of the Waghi valley on the interior plateau has been described as "cool and pleasant, with an absence of seasonal variation."[29] Morning mists are common, but they generally lift by 10:00 A.M. and bright sunshine prevails until mid-afternoon, when cold mists often drift in over the mountains. Afternoon showers are common, and light, intermittent rain occurs frequently at night. The rainfall in the plateau valleys varies from place to place and especially from lower to higher elevations, but in most parts prob-

** See Appendix D for climatic data for Lae and Nadzab.

[29] A. J. Bearup: "The Ramu and Waghi Valleys of New Guinea." *The Australian Geographer*, Vol. III, No. 1, May 1936, p. 8.

ably averages from 60 to 80 inches or more a year. Drought, as in the lowlands, is unknown, although dry spells lasting a week or two are not infrequent.

Chinnery [21] found a diurnal variation in temperature on the plateau near Mt. Hagen of 52 to 78 degrees. Keesing [22] states that in one part of the upper Ramu river valley, at 5,875 feet above sea level, records for 1938 show an extreme maximum temperature of 68.1 degrees and an extreme minimum of 54.8 degrees, with a monthly mean of 63 degrees. At scattered Australian outposts in these valleys it is customary to start a fire in the house in the late afternoon to provide warmth during the chill evenings. On several visits to places like Bena Bena, Garoka, Kerowagi, Chimbu and Mt. Hagen (all lying between 5,000 and 6,000 feet above sea level) we found it necessary to sleep under three or four blankets at night. Days are delightfully cool and I frequently found it necessary to wear a sweater or jacket, especially when clouds obscured the sun for any length of time, and in the early morning or late afternoon. It is hard to imagine without the personal experience the change in one's outlook on life that follows a brief visit to the plateau after several weeks in the lowlands. The morning after one's arrival (although sleeping late is perhaps the first temptation!) he is easily lured into going for a long jeep ride on the new road that has been built between Bena Bena and Mt. Hagen, walk to some native village in the vicinity to see at first hand how our own ancestors must have lived 10,000 years ago, or climb part way up one of the mountains close at hand. Two or three days in such an environment is enough to send one back to the lower elevations greatly revitalized.

The plateau with its pleasant climate holds one of the "master keys" to successful agricultural settlement of the broad, grassy plains of the Markham and Ramu valleys, in my opinion. Although it does not contain room for large-scale agricultural settlement by white people (i.e., several thousand) owing to the fact that the better valleys are nearly all closely settled by native farmers, there would seem to be sufficient room for rest camps and recreational facilities without disturbing the native way of life to any important degree, assuming the exercise of reasonable control over the activities and movements of white people on the plateau.

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[21] E. P. Chinnery: "The Central Ranges of the Mandated Territory of New Guinea, from Mt. Chapman to Mt. Hagen." *Geogr. Jour.*, Vol. LXXXIV, No. 5, 1934.

[22] Keesing, *op. cit.*, p. 42.

Thus the plateau could bear somewhat the same relationship to the lowlands that parts of the Atherton Tableland in northern Queensland now bear to the warm, humid lowlands in the vicinity of Cairns — an area where thousands of white settlers appear to have lived "successfully" for several generations. While it might be desirable for a limited number of settlers to have farms on the plateau producing crops that cannot be grown or do not thrive as well at lower elevations, the major role of the plateau valleys would be to provide rest and recreation in a temperate climate, with most of the settlers maintaining permanent homes and farms on the now uninhabited or sparsely inhabited grassy plains of the Markham and Ramu valley floors. Regular trips to the nearby plateau, such as many of the white residents of Batavia make to the high country around Bandoeng, could take the place of a long and expensive voyage to temperate parts of Australia every year or two to "cool off."

EFFECT OF CLIMATE UPON HEALTH AND ENERGY

Contradictory opinions have been put forward by numerous investigators on the effects of warm, moist atmospheres upon human health and energy.[23] Time does not permit a critical review of these opinions here, but it seems desirable to discuss briefly a few recent comments on this subject that have not yet received much attention in this country.

Referring to the effects of climate on military personnel in the lowlands of New Guinea in 1944, the Office of the Surgeon [24] reported as follows: "In general, no deleterious effects of climate on personnel have been observed among troops. Many commanding officers state that the efficiency of their men tends to be increased by a two-hour rest period during the hottest period of the day as evidenced by more concerted effort during other hours of activity. A system of six-hour work shifts which has been inaugurated will undoubtedly be of value. . . . The use of salt tablets is encouraged to combat the effects of profuse perspiration encountered in this climate. To date, no cases of heat exhaustion have been reported. . . . The entire matter of the effect of climate on personnel has not been subjected to critical, controlled experiments. . . . The observa-

[23] A. Grenfell Price: *White Settlers in the Tropics.* Amer. Geogr. Soc. Spec. Publ. No. 23, New York, 1939, pp. 6-8.

[24] Report, Office of the Surgeon, (U. S. A.) New Guinea Bases, 1944.

tion that the physical capacity for work is limited in the tropics is of course well established. The matter of mental alertness and mental deterioration however is more involved. Factors such as absence from home, military regimentation, unusual food, and uncertain future would seem of equal importance. . . . It would . . . appear that climate affects the non-effective rate . . . (of military personnel) . . . only indirectly and that the primary factors are the presence or absence of insect-borne and endemic diseases. . . ."

Macpherson,[25] reporting on tropical fatigue among RAAF ground crews stationed in various parts of the Pacific during the war, states: ". . . the incidence of illness is higher during a tropical tour than during a corresponding period in southern . . . (Australian) . . . states. (More factors than climate are probably concerned in this). . . . The "better type" of man, the one with the greater inner resources, adjusted himself better to the climate. The timid, the unsuccessful, the querulous, the self-considerate and those of low intelligence failed. . . . In units in which unit pride was high, adjustment to climate and surroundings was much more successful. . . . Well-disciplined men appeared to react better than the ill-disciplined. . . . Skilled musterings complained less of their circumstances than the unskilled . . . deterioration must contain a large mental factor. . . . No one would be so foolish as to assert that climatic conditions in the hot humid tropics are not trying. This aggressive climate must be met by aggressive prophylactic measures. . . ."

Lee [26] asserts: "Fatigue in the tropics is not essentially different from fatigue elsewhere; tropical conditions merely favour its development. The failure which is fatigue is partly physical, partly psychological. . . ." In another publication he adds,[27] "I cannot agree at all, however, with the pessimists that a stable European population cannot exist in the tropics, but I do doubt whether such a population can maintain physical and mental activity quite on a par with sub-tropical or temperate populations . . . a much more exact knowledge of physiological reactions to heat and the influence

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[25] R. K. Macpherson: "General Aspects of Tropical Fatigue as Seen in RAAF Ground Crew," Open Report No. 3, National Health and Medical Research Council Fatigue Laboratory, Brisbane, 4 Oct. 1945, pp. 5-9.

[26] Douglas H. K. Lee: "Physiologic Considerations in the Development of Tropical Centers," Open Report No. 1, National Health and Medical Research Council Fatigue Laboratory, Brisbane, 10 March, 1945, p. 2.

[27] Douglas H. K. Lee: "A Basis for the Study of Man's Reaction to Tropical Climates." Univ. of Qld. Papers, Dept. of Physiology, Vol. 1, No. 5, 1940, p. 49.

of various factors . . . (such as clothing, daily habits, housing, social contacts, etc.) . . . upon these reactions is essential."

It would appear from such remarks as these and from study of other literature [28] available to me at this time, that we do not have enough empirical evidence or experimental data on hand properly to evaluate the role of climate in human health and energy. We may, on the other hand, be justified in maintaining that a warm, humid atmosphere does not in itself necessarily preclude successful white settlement of the tropics, or that it does not constitute the chief barrier to such settlement. Such a climate does seem to have an enervating effect, however, especially on newcomers, and seems to require adaptation and a certain amount of adjustment of work schedules, diet, clothing, housing, etc. Its effect, whatever it may be, would seem on the basis of present evidence to be largely indirect, and therefore difficult to measure.

FORESTS AND GRASSLANDS

The most striking characteristic of the vegetation of the Markham and Ramu valleys, and of some of the interior valleys of the plateau, is the vast extent of grassland in an area of abundant, well-distributed rainfall, and moderate to high temperatures where dense forest would appear to be the logical climax growth. There appears to be no adequate "physical" explanation for this anomaly. The most likely explanation seems to be rooted in the native economy of the area. Marr [29] reports that old "devoru" (*Alstonia scholaris*) and other trees may be found scattered through the grasslands, indicating, he believes, that the land was originally covered with forest. He argues: "The present growth has been artificially caused by the shifting agricultural methods of the natives" and "the area is annually burned off for gardens and to drive out game like the bush rat, wallaby, and wild pig." (It is his belief that the grasslands would revert "quickly" to second-growth forest if there were no burning, but so thick and tough is the sod of these grasslands today that I am inclined to question his assumption that the process

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[28] See, for example, Mills: *Medical Climatology*, 1939; Z. T. Bercovitz: *Clinical Tropical Medicine*; C. H. Barber: *Tropical and Sub-Tropical Diseases*, 1942; Bulletins of the U. S. Army Medical Dept. for February, May, June and July 1945; H. M. Horack: *Medical and Sanitary Data on the Territory of Papua*, Army Medical Bull., Jan. 1943; D. B. McKinley: *Climate and Health*; E. Huntington: *Influence of Geography and Climate Upon History*, 1945.

[29] Marr, *op. cit.*, p. 8.

of reconversion to forest would be rapid. It might take several decades or even centuries.) Among the trees that are struggling for existence in the grasslands are hardy types like the thick-barked *Clerodendrons*. They succeed to a limited extent despite successive burnings. *Erythrina* species are common along the higher banks of the watercourses, where fire is not quite as effective a destructive agent.

I can testify to the potency of fire as an instrument for eliminating undesirable plant growth in New Guinea from experience in the Markham and Ramu valleys in 1944, when, during dry spells lasting a week or two, grass fires generating violent air currents extending thousands of feet in the air were visible everywhere in the valleys, and a pall of smoke at times completely obscuring the sun hung low over the plains for days at a time. The same condition was observed in the Waghi valley on the plateau in July, 1944. They were, in both instances, fires set by the natives to drive out game or to clear land for cultivation.

The forests.

For 10 or 12 miles up the Markham valley west of Lae a dense growth of tropical rainforest occupies the plains and extends well up most of the mountain slopes to the north and south. This forest consists of a great variety of indigenous hardwoods, many of which are suitable for general construction lumber. During the war this forest supplied allied forces in the Lae-Nadzab area with much constructional lumber, and valuable types including some classified locally as "mahogany" were used for commonplace purposes such as tent floors and packing crates. We cannot, however, be optimistic at this time in regard to a possible increase in the *commercial* exploitation of the hardwoods of this region. Lane-Poole[30] in 1924 found no areas of immediately exploitable timber in Papua, and no promising areas in the Mandated Territory. He did not then consider the outlook for commercial lumbering in the lowland hardwood belt very favorable, owing to the wide dispersion of useful species and the lack of transport facilities. He thought that there might be better prospects for sawmilling in the coniferous belt at higher altitudes, as the softwoods of Canada, the United States and Australia are reduced and transportation facilities in this part of

[30] C. E. Lane-Poole: The Forest Resources of the Territories of Papua and New Guinea. Govt. Printer, Canberra, 1925, 209 pp.

New Guinea are improved. It might, however, be pointed out that missions at Finschhafen and Alexishafen — fairly close to the Markham and Ramu valleys — had sawmills before the war that were cutting species of *Afzelia*, *Pterocarpus*, *Vitex*, *Calophyllum*, *Pometia* and softer woods for boxes.[31] In 1938 Lane-Poole stated that there are about 200 million board feet of New Guinea "pine" (*Araucaria cunninghamii* and *A. Klinkii*) in the Bulolo valley near Wau, and "this is but a tiny fraction of the softwood belt that girdles the Mandated Territory of New Guinea and Papua between 3,000 and 7,000 feet elevation." One of the commonest trees in the rainforest of the Lower Markham Valley * is *Afzelia* (*Intsia*) *bijuga*. This tree, according to Sparhawk,[32] reaches a height of 80 feet or more, and has a clear bole up to 50 feet in length. The wood is hard, heavy, yellowish or red-brown, has a mahogany-like grain, and is durable in the ground or in fresh water. It is considered to be one of the best timbers in New Guinea and the Philippines, where it is used for house posts, bridges, wharves, piling, poles, ties, paving, vehicles, implements and cabinet work. Another tree common to this area is *Alstonia scholaris*, which grows to a height of 120 feet with a clear bole up to 90 feet long. This wood is light yellow in color, soft, even-grained, fine-textured and easy to work. It is said to be suitable for light construction, ceilings, woodenware, and matches. The *Araucaria cunninghamii*, common in medium altitudes in this part of New Guinea, reaches a height of 150 feet or more and a diameter of five feet. The wood is similar to that of a true pine, and potentially the most valuable timber in New Guinea for general lumber.

Another tree that has been reported from this area, *Bombax malabaricum*, attains a bole 90 feet long and 7½ feet in diameter.

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[31] Quoted in W. N. Sparhawk: "Notes on Forests of Dutch New Guinea." Spec. Engr. Rept. No. 6, Strategic Studies Section, Intelligence Branch, Office of Chief Engr., U. S. Army, Washington, 1943. (Original reference is: C. E. Lane-Poole: *Annual Report of the Commonwealth Forestry Bureau for the Year 1938*. Canberra, 1939, 15 pp.)

* The rainforest on the valley floor (Marr, *op. cit.*, pp. 11 and 12), includes *Afzelia bijuga (Intsia bijuga)*, *Gnetum gnemon*, *Pometia pinnata*, *Breynia cernua*, *Albizzia moluccana*, *Albizzia alba*, *Chisochaeton biroi*, *Dysoxylon spp.*, and *Baccaurea* spp. On the lower mountain slopes are found *Celtis philippinensis*; *Pterocymbium* spp., *Octomeles sumatrana*, *Bombax malabaricum*, *Vitex cofassus*, *Morinda citrifolia*, *Chrysophyllum roxburghii*, *Planchonia timorensis* and *Alstonia scholaris*.

[32] Sparhawk, *op. cit.* (Detailed information on trees supplied here is condensed from my notes on the Sparhawk report which I saw in Brisbane, Australia, in 1944, and which is not now available to me. Hence page references cannot be supplied at this time.)

The wood of this tree is grey-brown in color, porous, soft, wooly-textured (yielding a type of kapok), straight-grained, light, and easy to work, though not durable. This wood is used in the Philippine Islands for fishnet floats and light household implements, and is probably suitable for boxes. *Celtis philippinensis*, which appears to predominate in the lower elevations in the Markham Valley, grows to a height of 120 feet and a diameter of 30 inches or more. The wood is yellowish or grey, hard, heavy, tough, difficult to split, though otherwise easy to work, and fairly durable. In the Philippine Islands it is used for beams, rafters, cheap construction, furniture and boxes.

Other woods reported in northeastern New Guinea and their uses include:

Chrysophyllum roxburghii: height, 120′; bole, 100′; diameter 30″. The wood is white and soft and is used in parts of New Guinea for making planks, box boards, and native houses.

Dysoxylon spp.: height, 80-100′; diameter, 2-3′. The wood is hard, heavy, variable in color, straight grained, easy to work and season, fairly strong and durable. Some species have the odor of cedar. The tree belongs to the mahogany family, and has uses in general construction, sashes and doors, furniture and cabinet work.

Octomeles sumatrana: height, 180-200′; diameter, 5′; bole, 100′. This is the largest and most magnificent hardwood tree in New Guinea. The wood is light brown in color, soft, light in weight, easy to work and season, and useful for all kinds of indoor work. It is often found in pure, even-aged stands on the alluvial bottomland and in pockets in the foothills, while in mature stands it forms a considerable part of the overstory.

Planchonia timorensis: height, 120′; diameter, 3′. This is one of the most abundant trees in the rainforest of southern Papua, and is also found in parts of the Markham Valley. The wood is reddish brown, hard, heavy, strong, and useful as a milling timber for general construction.

Pometia pinnata: height, 100′; diameter, 3′ or more. This is one of the most common trees on the alluvial flats. The wood is reddish brown with a walnut grain, hard, flexible, tough, moderately heavy to heavy, cross-grained and moderately durable. It has a fine, smooth texture, seasons well, is easy to work, and bends well when steamed. It is used for boat planks, general house construction, interior finish, masts and spars, handles, furniture and cabinet

work. Before the war it was one of the principal woods cut at Finschhafen on the Huon Peninsula of New Guinea.

Pterocymbium spp.: height, "tall"; diameter, 3′. The wood is soft, white or grey, straight-grained, light, seasons well, is easy to work, but not durable. It is used in the Philippine Islands for fish-net floats, boxes, temporary construction and matches, and is suitable for interior carpentry if kiln-dried.

Vitex cofassus: This is a fairly large tree. The wood is hard, brown, and makes a good construction timber although it is not durable in the ground. It is somewhat like teak, is used by the natives for paddles, and was cut in the sawmill at Finschhafen prior to the war.

Starting at 2,000-3,000 feet above sea level are large areas of hoop pine (*Araucaria klinkii*) growing alongside *Sarcocephalus* species. One species of the latter, *Sarcocephalus cordatus*, grows to a height of about 90 feet and a diameter of 30 inches. The wood is yellowish or white, soft, of medium weight, and a good substitute for pine. It seasons well, is easy to work, fairly durable, and is used in general house construction, boats, furniture, and cabinet work.

The grasslands.

The largest tracts of open grassland in the Markham Valley lie between Chivasing and Sangan although grasslands occur at intervals between Sangan and Kaiapit. The only trees between the two former villages are found along the tributaries of the Leron River. The grasses in this area consist of about 25 per cent "kunai"* (*Imperata spp.*) and 75 per cent kangaroo grass (*Themeda gigantea*) with *Saccharum spontaneum* on the damper ground. Wild sugar cane (*Saccharum robustum*) is found on the low-lying, stony river flats where the land is subject to flooding. Kunai grass is found on the better quality, deeper alluvium, and is gradually replaced by kangaroo grass on the poorer, stony soils such as those on the slopes of the valley. In places where the natives have consistently burned off these mountain slopes, kangaroo grass (*Themeda*

* The New Guinea Department of Agriculture ("What to Grow in the Islands," *New Guinea Agricultural Gazette*, Vol. 4, No. 1, 1938, p. 25) states that the word "Kunai" is of native origin, and the grass to which it refers is known as "illuk" in Ceylon, "lalang" (corruption of alang alang) in Malaya and the East Indies, "cogon" in the Philippines, "kuru kuru" in Papua, and "blady grass" in tropical Australia.

gigantea and *T. Amboinensis*) extends up to 3,000 feet above sea level.[33]

Large areas of grassland mingled with tree growth occur in the Nadzab area and in the upper portions of both the Markham and Ramu Valleys. Between Chivasing and Wowin a valuable hardwood is found (*Albizzia alba*) that is resistant to both fire and the attack of white ants (termites). On the moister land in this part of the valley are found *Albizzia moluccana* and *A. procera*. In general, the Markham Valley is covered with a very mixed growth of grasses, except for a few, small patches of pure kunai a few hundred acres in extent. The predominant species in order of their importance in the association are: *Imperata arundinacea* (*I. cylindrica*), *Themeda gigantea*, *Saccharum spontaneum*, *Imperata exalta*, *Eragrostis spp.*, *Paspalum spp.*, and *Polliniae spp.*[34]

On the poorer types of soil bordering the upper reaches of most rivers and their tributaries and on all grass-covered hills, *Anthistiria gigantea* predominates, completely eradicating kunai grass. On the higher land, *Andropogon serratus* is found, and to a lesser extent, *Cymbopogon nardus var. flexuosus*. It is possible that many more varieties of *Andropogoneae* thrive in these areas. There also appear to be many species of *Panicum* and *Paspalum*, and another good fodder grass known as *Pennisetum macrostachyum*, together with *Sorghum plumosum* (often referred to as *Andropogon australis*).[35]

The Role of Grasslands in Native Economy.

"Once the land is covered with cogon grass" (the "kunai" grass of New Guinea) says Pendleton,[36] "it can no longer be cultivated by the . . . (shifting cultivation) . . . method, so that, in so far as the local . . . food production . . . (is) . . . concerned, the land has become a grassy desert." Pelzer[37] also asserts that, "Once the vegetation of an area . . . (in the humid tropics) . . . has been changed from forest to grass, the land is of no more use to the shifting cultivator." This view, based on field observations in

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[33] Marr, *op. cit.*, p. 9.
[34] Marr, *op. cit.*, p. 10.
[35] Marr, *op. cit.*, p. 11.
[36] Robert L. Pendleton: "Some Interrelations Between Agriculture and Forestry Particularly in Thailand." Jour. Thailand Res. Soc., Natural History Suppl. Vol. XII, No. 1, 1939, p. 41.
[37] Karl J. Pelzer: *Pioneer Settlement in the Asiatic Tropics*. Amer. Geogr. Soc. Spec. Publ. No. 29, New York, 1945, p. 19.

Thailand, Malaya, the Netherlands East Indies (mainly Java and Sumatra) and the Philippine Islands, applies with certain reservations, to New Guinea. Natives, concentrated in large numbers on the valley floors of the interior plateau, and equipped with Stone-Age tools fashioned from stone and wood, repeatedly make use of tracts of grassland which are not allowed to revert to forest. These natives are quite capable of restoring to cultivation land that has been cleared, cultivated, abandoned after a year or two, and subsequently allowed to revert to grassland. Pressure of population in the plateau valleys has brought about the conversion of most of the once-forested valley floors either to temporarily cultivated garden plots or grassy "reserves" awaiting their turn at cultivation. Here it is not a question of choosing forest land or grassland for the next season's crops. The forest disappeared long ago, and has had no chance to return owing to the frequency of successive cultivations that a locally concentrated population requires.

In the lowlands the situation is usually different. The forests are vast and the population small. The natives are aware of the fact that virgin forest soils here often give high returns for a year or two and then decrease rapidly in fertility. Having no knowledge of the steel plowshare or the use of traction animals or mechanical equivalents, they usually find it easier and more profitable to ringbark the larger forest trees and clear out the undergrowth, harvest a crop or two, and then move on, than to dig out grass roots with their primitive tools. As long as primaeval forest remains they will largely neglect the grasslands, except for occasional burning in connection with hunting. Population pressure might eventually force them to concentrate their agricultural efforts upon the grasslands, as some of the highland tribes are forced to do now, yet there is no evidence that such pressure exists now. Nor does it seem likely that this will occur in the predictable future. The extensive grasslands of the Markham and Ramu valleys can probably be explained in terms of a relatively small number of natives armed with fire as a weapon of forest destruction, operating repeatedly over long periods of time.

Extensive grassy plains in middle latitudes have attracted large numbers of white settlers in the past who saw immediate opportunities for exploiting the native grass resource in a livestock or grain economy. We must exercise caution, however, in applying such experience to these culturally-induced grasslands of the humid

tropics. Superficially the latter suggest abundant fodder for livestock, but most of these grasses are reportedly deficient in available proteins, high in fibre content, and unpalatable to livestock. In the Markham and Ramu valleys there are said to be some good pasture grasses, but they are usually intermingled with many worthless species. In view of experience in other parts of New Guinea and elsewhere in the coastal lowlands of the humid tropics (e.g. Eastern Queensland) it would be unwise to assume that they have much value for grazing in their present condition, except perhaps for extensive cattle ranching utilizing tough breeds (such as the Zebu cross) and competing in the low-quality meat market. Dairying and high-quality meat production would in all probability require their replacement by a more nutritious and palatable sward, or supplementary feeding with concentrated foods, which would add considerably to the costs of development and upkeep.

SOIL FERTILITY

Pendleton,[38] Vageler,[39] Mohr[40] and others have done much to overcome the popular misconception about the "inexhaustible fertility" of tropical soils. This quite erroneous idea seems to have arisen partly as a result of the casual inspection of a few plantations and native gardens in more favorably situated parts of the tropics by travelers (some of them men of science, but not familiar with the tropics), and partly through false reasoning to the effect that luxuriant tropical rain forests with their profusion of woody and leafy growth could only develop on soils of great fertility. Thanks to more critical field work and station experimentation we now know better. High rainfall and high temperatures the year round permit luxurious vegetative growth on soils that may actually be deficient (for cultivated crops) in organic matter, potash, phosphate, nitrogen, "trace" elements like boron, cobalt, copper, etc., or other essential nutrients, and thus quite unsuited for agriculture which is dependent upon the sustained yield of crops that require specific soil ingredients in effective combination.

New Guinea soils *as a whole* seem to be no exception to the general

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[38] Pendleton, *Op. cit.*, pp. 36-37.

[39] P. Vageler: *Tropical Soils* (translated by H. Greene), p. 10.

[40] E. C. Jul. Mohr: The Soils of Equatorial Regions with Special Reference to the Netherlands East Indies. Amsterdam, 1933-1938. Translated from the Nederlandsch by Robert L. Pendleton, Ann Arbor, 1944. See especially section on Netherlands New Guinea, pp. 274-295.

rule that most tropical soils are poor soils. In many parts of the lowlands as well as on some of the upper mountain slopes, the leaching of plant and mineral nutrients from the upper parts of the soil profile has proceeded to a point where the soil must be considered infertile. In other areas the leaching process is not so far advanced and the soils can support native agriculture of the shifting cultivation type. Under the native system such land is cleared, planted for a year or two, and then abandoned in favor of a new clearing, thus allowing it to recoup some of its fertility before it is used again. In a few areas, however, alluvial soils have accumulated to considerable depths and despite a fairly high rainfall, the soils appear, at least on preliminary examination, to be well-supplied with most of the necessary plant foods. The soils of many parts of the Markham and Upper Ramu valleys and of some parts of the plateau valleys nearby seem to be of this nature, and may prove to be of potentially high agricultural value.

Marr [43] has provided us with some suggestive, preliminary information on the soils of the Markham Valley. He believes that the alluvium of the valley floor was laid down under estuarine conditions, judging from the occurrence of brown coal in some of the stream beds and the depth of fine silt commonly seen along the steep, high banks of the streams, where the surface loam is found practically unchanged at depths up to 20 feet. In fact, Marr claims that at no time during his reconnaissance survey did he find soil profiles deep enough to observe the transition from soil to subsoil. During the recent war, however, excavations for air strips, for building-foundations, and for sub-grading of highways gave opportunity to observe the contact between topsoil and subsoil in parts of the Lae-Nadzab and Gusap areas. On the margins of the valley the contact is commonly found from a few inches to a foot or two beneath the surface, but out on the plains it lies ordinarily at a depth of several feet, bearing out Marr's contention that some of the lowland topsoils are "unusually deep."

The natural fertility of the soils in the Markham and Ramu valleys does not seem to be consistent from one locality to another. In areas subject to periodic overflow the soils are mixed with quantities of sand and gravel, and with boulders near the foothills. This is especially true in the vicinity of the Markham, Manyang, and parts of the Ramu River valleys. According to Marr, "large areas of

[43] Marr, *op. cit.*, pp. 6-7.

fertile soil do occur, but equally large areas consist of shallow, stony soils which would probably not be worth cultivating, although they should eventually prove to be of considerable value for pastoral purposes." Marr adds that the land on both sides of the Leron River to a distance of several miles consists of gravel patches covered with a thin layer of soil varying from three inches to one foot in depth.

The soil away from the rivers is usually of superior quality. Toward the headwaters of the Markham the soils are "generally black, chocolate, or grey-colored medium . . . (textured) . . . loams with good subsoil drainage." Large areas of this type of land with a foot to 18 inches of soil may, according to Marr, be worth experimentation with shallow-rooted crops, since they are not deep enough for bananas, taro, yams and other more deeply-rooted crops and hence their use is not likely to interfere with the native food supply.

Deep, heavy soils of the Markham Valley usually carry a thick growth of "kunai" grass (*Imperata arundinacea*). Swampy areas carry cane grass (*Saccharum spontaneum*) and an unidentified type of reed. Soils of medium depth normally support a heavy growth of kunai mixed with a large kangaroo grass (*Themeda gigantea* or *Anthistiria sp.*). Shallow, stony soils are characterized by a sparse, short, kangaroo grass which is probably *Themeda elatior*, and by a smaller annual species. The incidence and growth of these grasses thus afford a partial guide to the character of the soil in the valley. Soils bearing kunai grass, for example, appear to be best suited for deeply rooted crops which tolerate a fairly high proportion of clay, specially in the subsoil. Areas where cane grass predominates are likely to be too swampy for most crops, though they may be suitable for "wet" rice. Where kangaroo grass dominates the plant association the soils, being shallow and stony, are probably unfit for cultivation, but suitable for pasture. Marr [42] concludes that "sufficient was seen to indicate that when this valley is opened up and land settlement is undertaken, as presumably will be the case, one of the first things to be done will be to make a careful soil survey of the whole area, since the character of the soil varies greatly and within short distances."

Samples of soil from the Upper Ramu Valley have been examined at the Waite Agricultural Research Institute in Adelaide, South

[42] Marr, *op. cit.*, p. 7.

Australia.[43] Two soil profiles, one from the alluvial flats and another representative of adjacent hill slopes, were found to be essentially similar, both being typical podzolized soils. The topsoil in both cases was a black to grey-black sandy loam rich in organic matter and about 12″ deep. Underlying this was a grey to yellow-brown, mottled, sandy clay or light clay subsoil. Ferruginous gravel to the extent of about 27 per cent was found in the alluvial profile and to the extent of about 40 per cent in the hill slope profile. Both soils were distinctly acid, with a pH of 5.0 — 5.5 in the surface soil and pH values up to 6.3 in the subsoil.* Both soils contained an adequate supply of plant nutrients such as nitrogen, potash, and phosphate.

Soil samples that I collected near Garoka on the plateau in June, 1944 and sent to the Waite Institute for examination are probably representative of many parts of the plateau valley floors between Bena Bena and Mt. Hagen. They were described by the Institute as follows: "Like most New Guinea soils they have a reasonably heavy texture and are well supplied with phosphate. They are less well supplied with potash."[44] These soils are less acid than those from the upper Ramu Valley mentioned above, having a pH reaction of 6.5 in the topsoil. Other soil samples from New Guinea have been examined by the Queensland Government's Department of Agriculture and Stock in Brisbane. In the case of eight samples tested for pH and available phosphate it was found that "the values obtained for pH indicate that the acidity of each sample is favorable for vegetable production. The available phosphate figure suggests that a fair state of fertility exists . . . (in five of the eight samples). . . ."[45]

Most New Guinea soils are probably somewhat acid. This is not necessarily unfavorable for vegetable production, or for certain commercial plantation crops, for example, coffee, or pineapples, which tolerate some acidity. If the acidity is found to be too great in parts of the area, it could be corrected by using lime. Limestone, some of it perhaps suitable as a source of agricultural lime, is plentiful locally. If the nitrogen content of the soils should prove

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[43] J. H. Hosking: Report on Soil Samples Forwarded by the Director of Agriculture, Rabaul, New Guinea, to the Waite Agricultural Research Institute. *New Guinea Agric. Gaz.*, Vol. 4, No. 1, Jan. 1938, p. 22.

* A pH of 7 is "neutral," i.e., neither acid nor alkaline.

[44] Letter from J. A. Prescott, Director, dated 10 August, 1944.

[45] Letter from Professor T. G. H. Jones, University of Queensland, Brisbane, 10 Sept. 1943.

low, it can be raised by applications of dried blood (readily available from Australian meat works) or sulphate of ammonia, both commonly used for fertilizer in Queensland agriculture. Potash can also be supplied where necessary.* It has been found that applications of potash are generally desirable in Queensland.[46] Most soils of the Markham-Ramu Valleys will probably not need applications of phosphate in the initial stages of agricultural development, though continued cropping would in all probability soon require such treatment.

It has become increasingly clear as a result of studies of tropical soils in recent years that the annual productivity of most tropical soils decreases at more rapid rates than those of most soils of middle latitudes when under intensive and continuous cultivation. A tropical forest soil often gives high initial returns for a year or two as the plant nutrients stored in the topsoil are drawn upon for crop production, but sustained yields comparable to those obtained on clay loams and loessial soils in Iowa, for example, are the exception rather than the rule. Huntington [47] reports that settlers in certain areas on the Brazilian plateau who obtained high yields of corn the first year found subsequent yields disappointingly small. Trumble [48] makes the same point for tropical soils in northern Australia and suggests caution in assuming that because army farms in New Guinea during the war gave high yields on virgin land, this land will be similarly productive under sustained cultivation.

Mohr [49] also stresses this "temporary fertility" of tropical forest soils and discusses its bearing on agricultural development in Netherlands New Guinea. Although his conclusions admittedly are based on deductive reasoning from geological and climatological studies (in the case of New Guinea) Mohr's familiarity with tropical soils in the Netherland East Indies justifies careful consideration of these deductions. Mohr states, "The continuous humid climate of these regions does not promote permanent conservation of the fertility. The chances are very good for finding soils which are physically good, but which are thoroughly leached (hence quite senile). In centers of cultivation such soils are more productive,

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* Obviously heavy applications of fertilizer will add measurably to the costs of production.

[46] Oral communication, L. G. Vallance, Assistant Research Officer, Dept. of Agriculture and Stock, Brisbane, 1944.

[47] Ellsworth Huntington, letter dated July 31, 1946.

[48] H. C. Trumble, oral communication, October 22, 1946.

[49] Mohr, *op. cit.*, pp. 274-295.

and yield greater profits than the virgin terrain of New Guinea. This is because it is practicable to incur considerable costs for fertilization, etc. in the more populated regions, where high value products are grown. Thus many hectares of land on the mountain ranges, where the forest is chopped down and burning is omitted, or is carried out very expertly, will, at first, give relatively astonishing harvests of various cultivated crops. But such fertility will last only until the plant nutrient reserves in the forest litter are consumed. When the crops begin to draw upon the reserves in the soil, there is very great need for replenishing what the everlasting rains have washed out. And then the problem arises as to whether or not the value of the crop will cover the cost. . . . Where autochthonous soil . . . (soil that has developed *in situ*) lies on marine limestone and marls . . . (as on the Huon Peninsula north of Finschhafen in the Mandated Territory) . . . the conditions for cultivation are as a rule less favorable. . . . If the limestones contain quartz sand, the soil is quite pervious. . . . The resulting lessened water capacity of these soils is a difficulty and a slight drought (for example, a rainless month) is a real danger. If on the contrary, as in the marls, the accessory material of the lime is mainly clay, then the soils are of greater water . . . (holding) . . . capacity. They are also chemically richer. But for many crops they are too dense and do not contain enough air . . . such soils are difficult to work and troublesome because they bulge out on slopes . . . the number of plains of promise is very meagre indeed. . . ."

Despite these rather pessimistic general conclusions, based on what Mohr himself describes as "indirect deductions from observations of an entirely different nature," the soils *in parts of New Guinea* would seem to be potentially productive. Witness these statements by Mohr: ". . . surface erosion removes from the tropical highlands surface soil of relatively higher value than in Central Europe. Erosion is thus more detrimental, and the silt coming from such highlands is of relatively more value than river silt in Central Europe. . . . On the schists of the Cyclops mountain range a soil of good physical characteristics has apparently developed. The parent rock is, on the average, rather rich in amphiboles, chlorite and biotite. Epidote, albite, and quartz, and sometimes calcite, play a part in the formation. . . . The allochthonous soils . . . (transported soils) . . . of the alluvial plains, under suitable management, may prove quite valuable. . . . New Guinea should not be considered as

a forgotten little corner of the world . . . in the course of a few thousand years tests of settlement and agriculture have repeatedly been made . . . (by the natives) . . . but unsatisfactory results have compelled giving up these tests. It would be quite otherwise, however, if a region is included in world commerce because it can produce high value world products such as Deli tobacco, Java coffee and quinine in place of low value food substances for an authoethonous . . . (indigenous or native) . . . population. If some day such crops might be discovered for New Guinea, then the whole situation would change. Then the land would blossom. . . .''

We are in no position at this time either to consider the soils of the Markham and Ramu valleys infertile, or to characterize them as fertile and proceed with concrete plans for their agricultural development. Native gardens and the scattering of army farms in this area during the war proved that high yields of a variety of vegetable and fruit crops may be obtained when either the rainforest or the grasslands are converted to farm land, for a year or two at any rate. How these soils may stand up to decades of cultivation and what their fertilizer requirements will become under prolonged use is another matter, and one that needs thorough investigation *prior* to the establishment of farm settlements in the region. We cannot afford to ignore experience accumulated over long periods of time in other parts of the rainy tropics, which indicates that most tropical soils are poor soils, and that thorough field investigations and laboratory examinations of soil samples should precede actual settlement in the remaining ''problem'' lands.

One further caution is here desirable. Modern soil science is fast revealing that so-called ''standard'' field investigations and chemical and physical analyses of soils in the laboratory are not enough. Soil samples should also be biologically tested in plant cultures to determine whether ''trace element'' deficiencies exist. Soil scientists are finding an ever increasing list of these ''trace'' or ''minor'' elements which, if not present in the soil in minute yet very important amounts, may result in crop failure or deficiency diseases in livestock (and perhaps human beings), which are dependent on plants growing in such soil for a living. Some of these important trace elements are boron, cobalt, copper, manganese, molybdenum, zinc and perhaps selenium. As far as I am aware no tests for the presence or absence of these elements have yet been made on the soils of the Markham and Ramu valleys. Yet this would be highly

desirable before any attempt is made to occupy these valleys for agricultural or pastoral purposes.

EXPERIENCE WITH ARMY FARMS IN NEW GUINEA

During the recent war many small "victory" gardens were cultivated by army personnel, or by groups of natives under military supervision, in the vicinity of military installations in various parts of New Guinea.[59] Men forced to subsist for months at a time on canned and dehydrated rations developed cravings for fresh food, and this caused hundreds of individuals to plant small plots of land in their bivouac areas with common garden vegetables and fruits, wherever the soil and climate were favorable and it appeared that the units were likely to be stationed in one place for three months or more. More elaborate farm projects, some of them over 100 acres in size, were developed at or near a few of the larger bases by both Australian and American forces to provide relief from the monotony of army fare and to improve morale. Priority on the supplies of fresh food produced on these farms was given to hospitals and combat units unable to plant their own gardens. Some of the more ambitious farm enterprises were located near Port Moresby, where both the Australians and Americans had large farms, at Oro Bay, Dobodura, between Lae and Nadzab in the Markham Valley, at Gusap, and on the plateau at Bena Bena, Garoka, Kerowagi and Mt. Hagen.

The farms at Port Moresby, while they suffered from early disappointments, were comparatively well-run and had sufficient native labor and agricultural machinery to meet minimum local requirements. They produced appreciable quantities of fresh food for troops remaining at that base, and limited amounts were sent by air to hospitals on the northern side of the island. The annual rainfall at Port Moresby is low (40″), and supplementary irrigation added substantially to costs of production, which were in the neighborhood of 3d. (5 cents) per pound.

The Oro Bay and Dobodura projects on the Buna plain were less successful, although the climate was more or less satisfactory, the soils fairly productive, and native gardens in the area had already demonstrated that good yields of a wide variety of crops could be

[59] Robert G. Bowman: Army Farms and Agricultural Development in the Southwest Pacific. Geogr. Rev., Vol. XXXVI, No. 3, 1946, pp. 420-446.

obtained on virgin soils for at least short periods of time without an exorbitant expenditure of energy or resorting to applications of fertilizer. Some of the reasons for the failure of these farms to live up fully to expectations were the withdrawal of units originally sponsoring the gardens; lack of suitable transportation; delay in the arrival of seed, machinery, spraying and dusting equipment; the planting (at Dobodura) of many acres in okra before it was discovered that most soldiers would not eat that vegetable; mildew, chiefly affecting cucumbers; lack of refrigerated storage facilities; lack of continuity in the planting program; and a long delay at Dobodura in the arrival of promised native labor due to medical quarantine, and subsequent failure to maintain an adequate labor force at the farm. (The sergeant in charge of the garden at Dobodura in May, 1944, told me he never knew from one day to the next how many natives would appear for work, and that consequently he was unable to plan his daily work program in advance.)

ANGAU officers stationed at Nadzab supervised the development of two gardens in that area, one on a grassy terrace near the Markham River at ANGAU headquarters, and the other about three miles east of that point deep in the rainforest. Both farms were designed to provide food for the native labor force employed in the area, and hence the emphasis was on crops preferred by the natives, such as sweet potatoes, corn, taro, "snake" beans, bananas and papayas. Several "European-type" crops were grown, however, and yields were good on the whole. At the second farm, the larger forest trees were ringbarked and left standing, and the ground remained a litter of stumps, logs and piles of brush with little semblance of order in the planting. No farm machinery was available, and all of the work was done by the natives with hand tools. Despite the lack of farm equipment and the heavy growth of timber, this farm was producing good-quality food crops four months from the time clearing commenced.

About half a mile east of the ANGAU farm an Australian farm company appropriated a hundred acres of low-lying alluvial soil on an old plantation adjacent to one of the small tributaries of the Markham River, at about the same time. This land had been partially cleared some years before the war and planted to coconuts, papayas, lemons, and bananas. The farm company was well-equipped with machinery, fertilizer, insecticides and fungicides, truck transportation, and enlisted personnel for labor, and was pre-

pared to create a large, modern, truck garden out of the former plantation clearings and virgin forest. Four months after occupation, however, less than 10 acres had been planted to vegetables. Floods washed out the first plantings, which were inadvisably located on low land close to the small stream. Preparation of the land was a slow process because of the rank growth of grass and trees in the area and the insistence upon eliminating all trees, logs and stumps prior to plowing. Stumps were dynamited or removed by bulldozers or with tractors and chains, and frequently after such treatment the land had to be regraded to provide good drainage and fill in surface depressions that would otherwise provide a hazard for agricultural machinery. The only crops that had been harvested four months after operations were begun were coconuts, bananas, lemons and papayas: crops that were the result of plantation enterprise years before and which had survived the neglect resulting from two years of abandonment. Eventually, this farm would have outstripped the ANGAU type of farm in productivity, assuming continuity of labor supply, availability of farm equipment, liberal use of fertilizers, adequate transportation and dependable markets. In the long run this is perhaps the best way to eliminate the dense forest growth and keep it (and the insect and fungous diseases that go along with it) under control. That this farm did not live up to expectations in 1944 is probably due to the fact that its sponsors were not sufficiently aware of the difficulties in bringing heavily forested land into production, and apparently did not take into account the increasing tempo of allied counter-invasions, the necessity for quick results or none, and the temporary nature of the local demand for garden produce.

Just west of the low divide between the Markham and Ramu rivers and near the air base at Gusap an enterprising American medical officer, Captain Shlimovitz, undertook the development of a vegetable garden late in 1944 to supply his unit with fresh food of local origin. Securing a plow, tractor, farm tools, a few enlisted men and natives, and seed, he plowed and planted about 15 acres of land on an alluvial fan on the south side of the valley. It was intended that this farm would later be expanded to about 30 acres, but the unit initiating the enterprise was moved out before this could be accomplished. By that time, however, sufficient produce such as corn, melons, beans and tomatoes had been harvested to show that the climate and soil were favorable for vegetable produc-

tion. The land near Gusap appears to be especially well-suited for intensive, large-scale cultivation with farm machinery. The extensive grasslands are easily prepared for planting; the rainfall is plentiful though not excessive; the soil is for the most part deep, well-supplied with organic matter, and well-drained; slopes are gentle; and the altitude of 1,200 feet together with the great topographic barriers enclosing the valley on the north and south is in large part responsible for somewhat lower temperatures and humidity than are found farther down the valleys of the Markham and Ramu. Dry spells are of longer duration here (an advantage in cultivation and in the harvest) and the definitely cooler nights and somewhat cooler days would seem to make the area more attractive to settlers.

Farms on the plateau have been described elsewhere [51] and it is desirable here merely to suggest certain possibilities for additional farm development on the plateau, especially in the way of supplementing production on the Markham and Ramu valley floors. The large native populations of most of the highland valleys preclude their use for farming on a large scale by new settlers. Yet sufficient room could be found, I believe, for a dozen or more small farms of 20 or 30 acres each. These farms could produce crops that cannot be grown successfully on the lowlands, and which would be desirable for providing variety in the diet of lowland settlers, such as green peas, head lettuce, cabbage, Irish potatoes, strawberries and raspberries, celery, cauliflower and the like. Such small scale activities, similar to what was actually undertaken during World War II, need not interfere with native land requirements to any significant degree. In addition to growing vegetables, they might well include supplementary pig-raising, bee-keeping, poultry farming, dairying, and rabbit farming, since the plateau valleys are well-suited for these enterprises. A few hundred acres would probably suffice to meet the needs of several thousand settlers in the lower valleys where land is not at such a premium. The natives would be left with plenty of opportunities in the way of cash crops, such as coffee, citrus, tobacco, tung, flax (in the higher valleys and cooler climates) or raising pigs for a Government cooperative bacon factory.

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[51] Bowman, *op. cit.*, pp. 437-440.

AREA OF CULTIVABLE LAND

Marr [52] estimates that the area of the plains of the Markham valley is 1,048 square miles. (This does not include, apparently, the Ramu valley or the forested strip near the mouth of the Markham river, but it does include the plains along the Watut river, a tributary of the Markham that enters the main valley southwest of Nadzab.) If the area of the gravel-strewn river beds is excluded, the area of the plains is reduced to 723 square miles or almost 463,000 acres. This is Marr's estimate of the area of cultivable land available for agricultural development.

There would appear to be almost as much additional land in the upper Ramu valley between Dumpu and Gusap suitable for cultivation, though less of this area is grassland and proportionately more of it light forest or (near the streams) dense rainforest. If we add the area of grassland and light forest of the Ramu drainage to Marr's estimate, we arrive at a total figure for the corridor as a whole of well in excess of 1,000 square miles, or over 640,000 acres of cultivable land.

The Mindanao Exploration Commission,[53] in a study of the possibilities for settlement on the grasslands of Bukidnon Province, Mindanao, concluded that 10,000 settlers would require a minimum of 100,000 arable acres of land, or about 10 arable acres per individual, "in order to provide an adequate standard of living together with proper use of the soil for the conservation of its fertility." The report stressed, however, that due to the nature of the local terrain it would be necessary in providing each family with 10 arable acres to include considerable areas of land suitable only for tree crops and stock raising. Further stress was given to the fact that while a Filipino family could get along quite well in a subsistence economy with from 12.5 to 30 acres of land (the size of the blocks involved in prewar subdivision of lands for Filipinos in Mindanao), European settlers accustomed to better living and under contract to repay substantial sums of money loaned to them would need at least 40 to 60 acres of land per family. This, it was claimed, would allow them "to farm on a larger and more intensive scale, with adequate rotation of fields, to insure maintenance

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[52] Marr, *op. cit.*, p. 5.

[53] Mindanao Exploration Commission (O. D. Hargis, S. Youngberg, R. L. Pendleton, H. F. Smith, H. J. Casey): Report of the Mindanao Exploration Commission, 1939, pp. 64 and 67.

of fertility and soil conservation, as well as necessary pasturage for livestock."

If detailed surveys of the Markham and Ramu valleys and field trials should prove that the area is potentially as productive, and as favorably situated, as that recommended for settlement in Bukidnon Province in Mindanao, we may on that basis assume 50 acres as the average amount of land required per farm family. There would accordingly be room in the Markham and Ramu valleys for some 12,800 farm families, or perhaps 60,000 people on farms, all told. If 100 acres of land (not necessarily all or even most of it arable) per farm family is found to be more desirable, there would still be room for 6,400 farm families, or, say, 30,000 people. Add to this the need for additional settlers engaged in various trades, professions, administration, services, etc., and these valleys conceivably might prove to be capable of supporting 100,000 people or more, at standards of living far superior to those maintained by the few, scattered natives in this area at present, or even those to which they may reasonably be expected to progress within the next century or more. One could hardly expect such settlements to rival older centers in Europe or the United States in terms of cultural advantages or employment opportunities, but there are people in this world who would accept (and even some who would prefer!) less than New York, London, Vienna, Rome or Sydney have to offer in the way of advantages. There are several thousand whites living successfully and through choice in Manila, P.I., for example, but neither the climate nor the scenery in the environs of Manila impress me as favorably as do those qualities in the Markham valley of New Guinea. The *potential* for another Manila may well exist in this part of New Guinea; the road to its achievement is certain to be a hard one. (The reconstruction of bomb-torn and shell-ravaged Manila will not be easy or inexpensive either!) But I can find no reason for believing it to be impossible if suitable types of people can be found to settle there, aided by the necessary urge to work, adequate capital, medical supervision, technical advisors and the like, and if it be fully realized that before neon signs and operatic tenors must come farms, access roads, trucks, warehouses, and villages.

I have been asked several times how *I* would like to live in New Guinea. My answer is that if I could find no home in the real sense of the word in Europe, the U. S. A., or in the British Dominions, I

would prefer the tropics to the aretic regions, and northeastern New Guinea to most other parts of the tropics!

CROP POSSIBILITIES

Most of the subsistence and commercial crops known to the world can probably be grown in one part or another of northeastern New Guinea.* On the more fertile soils of the well-drained alluvial lowlands many tropical plantation crops could be raised, as well as most tropical subsistence fruits and vegetables and some truck crops of "temperate" origin. Parts of the highlands seem well-suited for both tropical and temperate crops; sugarcane, taro, sweet potatoes, papayas, bananas and cassava, which are perhaps ordinarily considered lowland tropical crops, flourish 6,000 feet above sea level in the Waghi valley at Mt. Hagen and Kerowagi, alongside peas, sweet corn, strawberries, head lettuce, cabbage, cauliflower and carrots.

Subsistence Crops.

There would seem to be no great difficulty in providing settlers in the lowland valleys with almost every kind of food they are accustomed to eat without alienating large tracts of fertile soil in the highlands. During early 1944 it was the hope of 5th Air Force Headquarters to supply more than 40,000 air corps troops stationed at Nadzab with fresh vegetables and fruits from a few small (10-15 acre) farms on the plateau at Bena Bena, Garoka, Kerowagi and Mt. Hagen, supplemented in part by surplus products from native gardens in the vicinity of these four outposts. This project had the fullest possible backing of Australian officials at these plateau outposts, whose first estimates of the quantity of produce that could be made available exceeded even our own hopes. That the goal was never achieved was not due to lack of cooperation on the part of Australian officials, or to lack of good land, native labor, and suitable growing conditions, but rather to uncertain flying weather, lack of sufficient American transport planes and agricultural machinery when and where they were most needed, and the movement of most of the troops at Nadzab to other bases before much could be done to extend the area under cultivation and step

* Whether or not it would be *profitable* to grow them in New Guinea is another matter, and one reserved for later discussion.

up production on the plateau. (A list of the subsistence or minor crops that might be grown for local consumption in northeastern New Guinea, together with pertinent information about preferred varieties and growing conditions, appears in Appendix A.)

The question of *how* a food supply should be provided for local consumption cannot be answered until we know more about such matters as the optimum size for individual land holdings in this area, the amount of land that would be required for cash crops, the availability of transport facilities from one part of the valley floor to another and from highlands to valley floor, the availability of native labor for tasks that cannot be performed by machinery, and the availability of refrigerated storage facilities. Should each farm family provide most of its food supply from its own acres by its own hand labor? Should small groups of families pool their capital and labor and develop a communal farm? Should one or two large, scattered, truck farms in the lowlands and/or highlands provide the bulk of the food supply, allowing most of the settlers to concentrate their entire efforts on cash crops? Alternatively, would it be necessary or desirable to start with small, family fruit and vegetable gardens and gradually replace them with cash crops?

In this connection, it is worth while noting that in the United States a farmer and one helper with appropriate modern machinery can run a 50-100 acre vegetable farm, whereas with hand labor two or three men are needed for every acre.[54] In New Guinea more hand labor may be required for the same acreage, but the ratio between the amount of labor required for a farm of the first type and one of the second type should not be very different. Now, agricultural specialists with years of experience in the tropics, and who were serving with the Quartermaster Corps of the U. S. Army in the southwest Pacific during the war, have estimated that a farm of 300-400 acres in the tropical islands north of Australia should provide enough fresh vegetables for the equivalent of one meal per day for 10,000 men.[55] A farm of 1500-2000 acres, therefore, would probably suffice for a population of 50,000, if it could be centrally located and there were adequate facilities for refrigerated storage

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[54] Oral communication from Major B. F. Seabrook, Procurement Division, USASOS, Melbourne, March 14, 1944. (Major Seabrook is one of the owners of Seabrook Farms in New Jersey, principal suppliers of Birdseye Frozen Food Products.)

[55] Lawrence H. Phillips: Review of Food Production Plans for New Guinea: Headquarters, Advance Quartermaster Depot No. 1, Advance Sub-Base D, 4 August 1943.

and distribution. Two farms of 750-1000 acres apiece, one located in the upper Markham valley and specializing for the most part in tropical fruits and vegetables and the other on the plateau specializing in crops better suited to a cool climate, might be still better, assuming good transport connections between the valley and the plateau. Machinery to perform many of the heavier farm operations could be made available at the two sites, together with sufficient operators and laborers for performing tasks unsuited to agricultural machinery. The farm in the valley might have to rely on white labor if sufficient native labor could not be recruited, but on the plateau there is an abundance of native labor with centuries of experience in vegetable and fruit growing, though not of the large-scale scientific type suggested here. Such a plan as this would enable settlers in the lowland areas to use their capital for the purchase of specialized equipment needed for producing cash crops for export abroad, and avoid duplication and inefficient use of the machinery and hand tools required for vegetable growing on small holdings. It would also relieve them (particularly the women) from spending long hours in household gardens producing food for table use. It would seem on the whole to be a more efficient way of handling the local food problem, and has the following additional advantages:

1) Control of insect pests and fungous diseases would be simpler and less costly.
2) Distribution of seed, fertilizers, insecticides, fungicides, etc., would not have to be made periodically to a large number of sites.
3) Safe storage of seed, always a problem in the humid tropics, could be more easily and cheaply provided at one or two locations.
4) Ample refrigerated storage facilities could be provided at one or two locations to care for temporary surpluses and provide a reserve of fresh food for times when production is low. This would assure an abundance of a wide variety of fresh fruits and vegetables at all times of the year.
5) Specialization of this type would insure the use of the most scientific methods of production, particularly if an experimental station or two is operated in conjunction with the farm activities and if skilled personnel are attached to the farms. This would seem to be more in line with recent trends in

vegetable growing in the United States, especially in the highly organized and efficient frozen foods industry.

Control of insect pests and plant diseases.

The consensus of opinion among tropical agriculturalists in New Guinea and Australia seems to be that control of insect pests and plant diseases should not be very different in New Guinea, or more difficult, than in tropical Australia (East Queensland), the Netherlands East Indies, or other parts of the tropics where similar environmental conditions are found. Essentially the same crop pests and diseases seem to be present, as far as is known, and there is little or no reason to believe their rates of increase or spread will differ markedly from those which prevail in the Cairns district of northeastern Queensland or in the warm, humid lowlands of Java. Progress in the field of insect and plant disease control has been fairly rapid in recent years (although we do seem to have to cope with an ever greater variety of such evils) and experience gained only after costly research and heavy crop losses in other parts of the humid tropics could probably be used to advantage in New Guinea.

Suggestions for the control of some of the insect pests and plant diseases that are known to be a hazard in vegetable growing in New Guinea, or which might become a problem there, appear in APPENDIX B.

Cash Crops.

The New Guinea Department of Agriculture [56] informs us that coconuts were the first commercial crop to be cultivated in New Guinea. The export of copra, the dried meat of the coconut, reached 76,000 tons in 1937. The local industry, however, was suffering from lack of sufficient labor and the low world price of copra shortly before the war and "there is little likelihood of expansion of the desicated coconut industry at present . . . to compete successfully in the copra trade it will be necessary to lower costs and improve the quality."

Of the prospects for most other commercial crops, the New Guinea Department of Agriculture [57] just before the war was not optimistic:

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[56] New Guinea Dep't of Agriculture: What to Grow in the Islands. *New Guinea Agric. Gaz.*, Vol. 4, No. 1, 1938, pp. 25-31.

[57] New Guinea Dep't of Agriculture, *op. cit.*, pp. 28-31.

Pimento. This crop has a limited demand and is grown almost exclusively in Jamaica where it is little more than a peasant crop.

Nutmeg. This takes years to bear, requires careful handling and packing, and ruling prices (1938) "do not justify any planter growing them extensively." Nutmegs are extremely sensitive to insect attack after harvesting, and must be wrapped in paper individually and the seams of the boxes sealed with tape.

Cloves. The market is limited and in normal times well supplied by Paemba and Zanzibar (British Protectorate) and the Moluccа Islands, Netherlands East Indies.

Pepper takes six years to reach full production, and requires as intensive cultivation as a market garden. In 1938 there were 25,000 tons on the London market, though ordinarily the stock is about 4,000 tons.

Arrow root, Ginger, Cardamons, Cinnamon. "The market is limited and expansion unwarranted."

Vanilla has "great possibilities but only as a side line." This plant is an orchid and in New Guinea must be hand-pollinated to get any crop.

Manila hemp, Sanseviera hemp, Mauritius hemp and *Jute.* These fiber crops "cannot be grown profitably in New Guinea at present. An improved variety or sub-species of sisal hemp could probably be grown profitably if cultivation were on a very extensive scale and under able management." Much expensive machinery would be necessary. The same is true of tapioca, although this crop is more easily produced. Production on a profitable commercial scale by European planters requires considerable financial resources on account of the machinery needed in its preparation.

Derris root. Samples sent from New Guinea in 1938 to the Imperial Institute in London showed a rotenone content of about four percent, comparing favorably with the Malay product. Experiments were being carried on at Rabaul in 1938 with *Derris malaccensis*, an imported type. The plant takes about 21 months to produce roots ready for harvest. (This crop may prove important for New Guinea, as millions of pounds of rotenone are now required in the United States and other countries for insecticides, and it is likely that the demand will increase.)

Adlay is a cereal crop introduced to New Guinea from the Philippines. It grows very well in New Guinea, but its taste is unfamiliar both to natives and Europeans. The grain is appreciated by poultry.

The few tropical crops left that could be grown profitably in New Guinea, according to the Department of Agriculture in 1938, are *cacao*, *rubber*, *coffee*, (*Coffea arabica* and *Coffea robusta*), *tea*, *cinchona*, *kapok*, *West African oil palm*, and *sugar*. Tea and cinchona were recently introduced to the Upper Ramu valley at 6,000 feet elevation. At the agricultural station at Wau, coffee (*Coffea arabica*) of the Blue Mountain variety, imported from Jamaica, is grown at 3,000 feet elevation. The trees "yield heavy crops of excellent quality which find a ready market." The "rich mountain lands on the Upper Ramu and many other parts of New Guinea are eminently suitable for Arabian coffee, high quality tea and cinchona, but it is useless to consider their cultivation until roads are constructed to the interior." Due to the large demand for rubber in Australia "there are possibilities of this crop being worked on a profitable basis if up-to-date methods are employed." In order to compete on the open world market it would be necessary to get specially selected, high-yielding clones similar to those found in Malaya and the Netherlands East Indies which yield 2,000 pounds or more of dry rubber per acre. (The present yield in Papua is probably not over 700 pounds per acre.) Agreements between the main rubber-producing countries have long prohibited the export of these high-yielding clones, but similar ones might be found by careful search of the Papuan plantations.

The prospects for commercial crops in New Guinea, states the New Guinea Department of Agriculture,* are therefore:

1. *Rubber* at low and medium elevations.
2. *Cacao* at low and medium elevations.
3. Coffee (*Coffea robusta*) at low and medium elevations.
4. Coffee (*Coffea arabica*) at elevations of 3,000 feet and up. (Upper limit 7,000 feet.)
5. *Tea* at elevations of 3,000 feet to 5,000 feet. ("Up-country" type.)
6. *Kapok* can be grown successfully in many types of soil, from near sea level to medium elevations.
7. *Sisal hemp*. A new variety of a species developed at Amani Agricultural Research Station (Tanganyika) is reported to have doubled the percentage of fiber produced by *Agave sisalana*, and to be of much finer quality. Suckers were requested before the war for trial in New Guinea.

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* But see also Appendix D.

8. *Tobacco* has possibilities in New Guinea though "it is somewhat of a gambler's crop yielding high returns at one time and failure at others owing to susceptibility to disease and insect attack."

9. Low country *tea* and *cotton* have proved unreliable and unprofitable.

10. *Derris root* has "reasonable prospects" in New Guinea, and has been grown experimentally at the Karavat Demonstration Station at Rabaul.

11. *Pepper* is hardly suitable for cultivation by Europeans except as a side line. Commercial pepper is almost entirely grown by Chinese and Malays under highly intensive cultivation like a market garden.

12. *Spices* and many other minor crops are only suitable for peasant or native cultivation.

Certain writers [58] in recent years have at times and with some reservations taken a rather pessimistic view of prospects for agricultural development of the tropics by white people partly on the basis of past experience of white settlers in tropical lands and partly because they see no lucrative new crop possibilities. They point out that most of the world's chief food and commercial crops have been known to man for thousands of years and suggest that it is "unlikely" many new ones will turn up to revolutionize agricultural prospects. We cannot afford, however, to ignore the recent rapid progress of industrial chemistry in putting familiar substances to new uses. Our greatly increased industrial needs and techniques are likely to push experimentation on hitherto valueless or low-value plants, especially in the tropics, that have thus far largely or wholly escaped the attention of commercial entrepreneurs. New Guinea, for example, is still imperfectly explored by plant ecologists and may well deserve greater attention. The example of derris and its recent commercial importance as the source of a potent insecticide should not be forgotten, though it is true that the plant is not newly discovered, having long been used by the natives of New Guinea and elsewhere as a fish-stupefier.

New uses for old plants may require a change in current attitudes towards the prospects for agricultural development in the tropics,

[58] See, for example, C. O. Sauer: The Prospect for Redistribution of Population, *Limits of Land Settlement* (ed. by Isaiah Bowman), Rept. to Tenth Ann. Studies Conference, Paris, 1937, pp. 7-24.

redirecting our attention toward further settlement in these lands. We cannot afford to neglect the possibilities or be unprepared to take advantage of the opportunities once they are presented. Past experiences of white settlers in the tropics should not be ignored, but neither should they blind us to possibilities for successful settlement there in the future when new forces, new requirements, new discoveries and inventions may appear on the horizon. Idle land suitable for cultivation in New Guinea will probably be put to use ultimately somehow, by someone.

Twenty years ago few if any persons believed that New Guinea could produce $10,000,000 worth of gold in a single year, yet that has been accomplished as a result of the recent discovery and exploitation of the Wau goldfields. Ten years ago few people would have been willing to invest in oil-prospecting in New Guinea, yet several large companies have recently been spending hundreds of thousands of dollars in test-drilling there. Some people today see little opportunity for agricultural settlement on this island, but as in the case of the oil and the gold, it is not impossible that the soils of certain parts of New Guinea will prove a magnet that we cannot long afford to ignore.

The Markham and Ramu valleys and parts of the plateau nearby appear to offer some rather favorable opportunities for taking advantage of these discoveries of new uses for old crops. There is a large area of unused or infrequently used land in the lowlands, a wide variety of soils and climates, and the area could be made accessible from the seacoast (where there is already a good port at Lae) by the construction of an all-weather highway that poses no very complicated engineering problems. This is perhaps enough to warrant further study and experiment, and perhaps eventually the establishment of a small trial colony. If such efforts show that the land can be made productive under scientific practice and good management, the contrasts in the physical environment of the region as a whole would seem to favor diversified agriculture and discourage dependence on a single crop or a narrow range of crops — the chief economic problem in many plantation areas.

By way of illustration of some of these economic problems connected with agriculture specialization in New Guinea, let us consider quinine. The growing of cinchona for the production of quinine, a crop recommended by the New Guinea Department of Agriculture, is not a project to be lightly undertaken. A report

from the Philippines,[59] where a few plantations of cinchona have recently been started, states that "no other culture requires such rigorous, unremitting, scientific control." The Dutch in the Netherlands East Indies before the recent war had gained control of 97 per cent of the world's production of quinine by persistent attention to scientific control of every operation and detail of cultivation. They improved and stabilized their competitive position by selection and plant breeding, followed by propagation of superior clones available only to themselves. They spared no expense, and as a result of their labors and sacrifices had a virtual monopoly of world trade in this product. The potential productive capacity of Java alone is said to be sufficient to meet the world's needs.

One naturally asks, "Why try to compete in this field"? Perhaps the answer, at least as far as the Philippines are concerned, is that a tropical country which produces very largely the same products as Java, and many of these in excess, has little to exchange for Java quinine. Such countries, it is argued, had better produce at home for home consumption whatever they can, if it can be done at all economically, and buy abroad what they must. With imported quinine as expensive as it is and available to only about 10 per cent of the Philippine population (the wealthy and near-wealthy), the majority of the people must still suffer the ravages of malaria.

If this be true of the Philippines it should also be true in New Guinea, where most of the natives are without money and have little except their labor to exchange for quinine and other imported products. A local supply would relieve the Government from dependence on Java quinine bought at monopoly-controlled prices and save foreign credits for the purchase of other goods that New Guinea is not now capable of producing.

Quinine, however, now faces serious competition from atabrine, the synthetic malaria suppressive, and we do not yet know whether we can find ways of mass-producing the newly discovered synthetic quinine at costs below the natural product. Neither quinine nor atabrine is a malaria *preventative*, furthermore, and the search continues with increasing likelihood of success for a substance that will serve this purpose and render both atabrine and quinine obsolete.

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[59] Joaquin Marañon and Hartley H. Bartlett: Cinchona Cultivation and the Production of Totaquina in the Philippines. Univ. of the Philipp., Nat'l and Appl. Sci. Bull., Vol. VIII, No. 2, Mar. 1941, p. 133.

AVAILABILITY OF NATIVE LABOR

The native population of the Mandated Territory of New Guinea is now estimated at about 590,000.[60] Most of the natives live in small villages along or close to the coast, on the better drained parts of the interior plains, and in valleys on the plateau, where some may be found on individual farms and in scattered dwellings and others in small villages. Their numbers have decreased recently in some districts, especially near the coast, and slowly increased in others. It is stated that "in the areas under white control the native population has been stationary or has increased but little."[61]

I am unable to find any official count or reliable estimate of the number of natives in the Markham and Ramu valleys and the plateau valleys immediately south of them.* There must be several thousand natives in scattered villages through the Markham valley and the upper third of the Ramu, and it has been estimated[62] that there are at least two hundred thousand in the plateau valleys between Mt. Kratke and Mt. Hagen, where the population can be considered relatively dense in relation to the amount of arable land available for the shifting cultivation that is practiced. It has already been pointed out that in the Markham and Ramu valleys the natives make very little use of the extensive grasslands, and then only at infrequent intervals for the purpose of securing wild game, so that settlement of parts of these valleys by white peoples would not necessarily require the resettlement of many natives or serious interference with native food supply.

There is disagreement among Australians as to what constitutes a sound native policy for New Guinea and how it should be applied. Policy in the past has varied from time to time and from place to place as administrations changed or as more was learned about native customs and needs. The Government has generally tried to live up to the terms under which the Mandate was granted to Australia, that it shall administer the territory in such a way "as to promote to the utmost the national and moral well-being and social progress of the inhabitants," without appearing certain at

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[60] W. I. Ladejinsky: "Island Agriculture in the South Pacific," *Foreign Agriculture*, Vol. 7, No. 8, Aug. 1943, pp. 178-184.

[61] Roberts, *op. cit.*, pp. 99-100, 122.

* A friend of mine in New Guinea (John B. Mackay) recently wrote me that he had been employed for over two months taking a census in the Madang area, north of the Markham-Ramu valleys. He covered "just on 1000 miles" by pinnace and jeep to record 366 people!

[62] Elkin, *op. cit.*, p. 35.

times as to how this could best be accomplished. It has, furthermore, been subjected to various kinds and degrees of political pressure from plantation, mission, trading, mining, petroleum and other interests concerned with the development of local resources or the extension of influence. Anthropologists familiar with native life in New Guinea have recently been urging a more enlightened and intelligent attitude toward the native, especially as regards the discontinuation of contract or indentured labor and the need for adapting policy to local conditions, which vary tremendously from one part of the Mandate to another.[83]

The chief problem of the coastal planter in New Guinea is how to get adequate labor for his plantation.[84] The available labor supply in coastal regions of Papua and the Mandated Territory is small because the native population is small and widely dispersed, and because there is very little incentive for natives to work on plantations. Elkin[85] states: "as it becomes harder to get labor, professional recruiters endeavor to maintain the supply, for which the employer pays them about £10 for each man signed on . . . in order to fulfill requirements, a professional recruiter has to go hundreds of miles into a malaria-infested country in a wretched little pinnace of which he himself is the owner, skipper and engineer, or perhaps in some cases in a hired canoe, armed with a large assortment of trade, for the purpose of inducing Stone Age natives to come and work for the white man. In doing this he faces much hardship, considerable danger, and may strike bad luck and come back sick and empty-handed; or he may be murdered." The Government, furthermore, has imposed many restrictions on labor recruiting and insists that certain standards of health services, clothing, housing, hours, food and proper supervision be met by plantation owners. This may be a good thing from the standpoint of the native, but it increases the planter's difficulties and expenses in signing on labor, as well as other costs of production.

Government officials in New Guinea now contend that no more than five per cent of the total native population of an area should be drawn upon for labor supply, or put in another way, 30-33 per cent of the "fit adult male population." If more natives are withdrawn from villages and farms for work on plantations there is

[83] Elkin, *op. cit.*, pp. 23-27.
[84] Wood, *op. cit.*, p. 85.
[85] Elkin, *op. cit.*, p. 25.

likely to be serious disorganization of native life and attendant famine.

Prior to the recent war, native labor was secured by means of the contract system, whereby a native would agree to work for a specified period — one, two, or three years — and if he left his work to return to his village before his time was up he could be apprehended and brought back to work out his term. During the war, conscription was in effect in some coastal regions of New Guinea. It is probable that neither practice will continue long into the post war period. Speaking on the indenture or contract system of native labor, Sir Hubert Murray [66] has said, "It is not an institution which anyone who knows anything about it would care to perpetuate . . . it is not in the best interests of native welfare . . . (and) . . . it is a tottering relic of the age when the native was deemed to be 'plantation fodder' for the white exploiter. . . ."

It would appear that intensive agricultural development of the Markham and Ramu valleys is unlikely to be accomplished by the natives themselves for a long time to come, if ever. It is even doubtful if much will be accomplished with native labor working under white supervision along current lines in New Guinea, in view of the lack of incentive, the difficulty of getting native labor nearly everywhere in the lowlands of New Guinea, and government policy toward conscription, indenture, and overdrafts on the male population of native villages. Since highland natives — as yet largely untapped as a labor supply — cannot be brought down to the thinly populated lowlands without running grave risks from diseases to which they have built up no immunity, the further development of the lowlands would seem to depend either upon migration of laborers from southeast Asia or upon white agricultural settlement in which farm machinery largely or wholly replaces native labor.

There is little difficulty in recruiting native labor in the well-populated valleys on the plateau. When our C-47 transport plane crashed near Kerowagi in November, 1944, the Australian officer in charge of the Kerowagi-Chimbu area sent out a call for natives to come to the scene of the crash and haul our plane up to the ridge-top airstrip that we had overshot. Next morning at least a thousand stalwart natives were gathered at Kerowagi to assist us. Everywhere in the Waghi valley one sees thousands of natives working on the jeep roads, tending gardens, or just sitting around houses in the

[66] Quoted in Roberts, *op. cit.*, p. 211.

villages or near the Government stations doing nothing. These plateau natives are different from lowland types, both in appearance and in attitudes toward work. They are stocky, muscular people, as a rule, and display tremendous energy when there seems to be any need or desire for it, or chance of reward. I have seen work gangs coming in with wood from the mountains late in the day, shouting, singing, laughing and frequently running, although they were carrying heavy loads and may already have made many trips that day to the forest several miles away. Tribal warfare previously took up much of the time and energy of these men, who now form a great labor reserve upon which the few Australians on the plateau make but limited demands for constructing roads and Government buildings. A native on the plateau will do a month's work for a tomahawk (hatchet), a "kina" shell, a little salt and tinned food, a few sticks of "rope twist" tobacco and some paint pigment to smear on his body.

The highland natives are perhaps not "efficient" laborers when judged by western standards, but they learn surprisingly fast at times and seem generally eager to work. In a matter of a few weeks during the war some of them learned to be excellent (if occasionally nerve-shattering!) jeep drivers and one fourteen year old boy I met had become on very short notice an expert tommy-gunner. Native labor of this type, however, must be under the supervision of trained white personnel when performing unfamiliar tasks or working in very large groups, and much of the good work the Australians have done toward training the natives in the last decade could be wiped out in a short time by either harsh or excessively lenient treatment. The natives have many taboos and superstitions, with which managers must be familiar if they are to get the natives to work satisfactorily. Natives ordinarily will respond well to fair treatment, which is generally accorded them by "old hands" in New Guinea. Elkin [67] is not boasting when he states that "Australia can take some justifiable pride in its native administration."

TRANSPORTATION FACILITIES AND NEEDS

The recent war wrought many changes in New Guinea — some bad and some good. Among the good was the construction of an all-weather highway across the Owen-Stanley range from Port Moresby

[67] Elkin, *op. cit.*, p. 51.

to Buna on the north coast, and of numerous shorter but equally well-built access roads in other parts of the island. A good, two-lane, all-weather road, for example, was constructed from the port of Lae to Nadzab, 15 miles up the Markham valley where six air strips were located. Nadzab during the early part of 1944 was the largest advance air base in the Pacific theater, and was occupied by over 40,000 Air Corps personnel as well as associated ground forces. The walls of the great corridor leading to the Japanese bases at Wewak and Hollandia echoed almost continuously the roar of passing aircraft based at Nadzab and Gusap, and much of the Markham valley was a beehive of both ground and air activity. Roads and several large air strips were built at Gusap, a base that was supplied entirely by air. Lae became one of the busiest Allied ports in the Pacific theater for a time, and was capable of docking three or more Liberty ships simultaneously while dozens of others lay at anchor in the spacious roadstead in Huon Gulf. Telephone communications were established between Gusap and Lae. Gasoline-powered generators supplied electrical power for the myriads of lights that at night marked the sprawling "city" of Nadzab, the "town" of Gusap, and the port of Lae. Ships were unloaded on a 24-hour schedule, trucks rumbled up and down the highways night and day, and planes took off from the landing strips and returned thereto "around the clock."

Today for the most part the valley is silent and such life as remains has settled down again to a peace-time routine. Nearly all the soldiers have gone; many of the buildings have been torn down; few planes are seen; only an occasional ship docks at Lae, the capital of the Mandated Territory; thousands of miles of insulated wire lie rotting on the ground or sagging between makeshift poles; heavy trucks no longer roll in endless streams up and down the highways, churning up great clouds of dust in dry weather and gobs of mud in heavy downpours; and the ubiquitous kunai grass forces its way upward through holes in the rusting piereed steel planks on the air strips and eracks in the disintegrating wooden platforms where tents once stood in more or less orderly array at various headquarters of the gigantic military establishment.

There remain, however, enough of the works of the white man to indicate his former presence here and there for some time to come, and to aid somewhat in the development of the valley if that is undertaken in the near future. The port of Lae is now one of the

best on the north coast of New Guinea, with several docks still in good condition and rows of warehouses among the coconut trees north of town. The highway leading to Nadzab and the open grasslands beyond remains (though sections are now classed as "impassable") and so do the clearings and graded surfaces of the former air strips at Lae, Nadzab and Gusap, as well as those kept in operational condition on the plateau at Bena Bena, Garoka, Kerowagi and Mt. Hagen, and the jeep road linking these outposts. Concrete foundations at several of the headquarters at Nadzab have probably not yet crumbled entirely under the attack of rain and sun.

No great engineering feats would have to be performed to provide a good, all-weather highway between the port of Lae and Gusap near the divide between the Markham and Ramu rivers. There are no steep grades and the wide, shallow river beds could either be bridged or forded. There would, for that matter, be no great difficulty in building a railroad from Lae to Dumpu, if this were desirable. Some air strips in key locations could be put back into operational use without great expenditure of time and money.

The chief problem from the engineering standpoint, aside from bridging or providing suitable fords over the river beds on the lowland plains, would be the building of an access road to the plateau. The country is rough between the Markham River and Kainantu, the eastern terminus of the present jeep road on the plateau, with sharp ridges separating the deep, gorge-like valleys in which flow swift mountain streams. Native labor could be used to improve the present road on the plateau and perhaps extend it somewhat farther to the east, for labor is abundant there and quite capable of performing these tasks. Heavy earth-moving machinery would be desirable for some of the work, however, and there would have to be several bridges built and either tunnels or deep cuts (probably the latter owing to the frequency of earthquakes in this region) made in several places. A first class military highway was built over more difficult terrain and for a much greater distance between Port Moresby and Buna early in the war, as well as one from Wau to the north coast. American engineers and Australian Government officials with whom I talked in New Guinea in 1944 told me that a good connecting highway between the plateau and the coast would be difficult and fairly expensive to build, but certainly not impossible to construct. There are in fact some people in New Guinea who maintain that such a road will have to be built sometime in the

future to tap the resources of the interior and extend the Government's influence more effectively to remote valleys all the way to the Dutch border. Only negligible development of the interior of the western half of the Mandate can take place without it, unless the air age provides some unexpected miracles of low-cost, bulk transport. Even this would not wholly solve the problem of regular contact between the interior and the coast because the weather is frequently so bad over the ranges flanking the plateau that planes cannot get in or out, sometimes for days on end. A connecting road, moreover, would greatly aid the administration in its avowed aim to improve the lot of the natives in the interior in line with the terms under which the Mandate was granted to Australia.

LOCATION AND DESIGN OF HOUSES

One can hardly overemphasize the importance of proper siting and house construction in the planning of tropical settlements. In most parts of the tropics to which white settlers have migrated, the choices of location and types of house construction reflect the prejudices of the settlers' homelands, without regard to their suitability to tropical conditions. It is imperative that some of these prejudices and habits be overcome in planning future settlements in the tropics, if they are to have a reasonable chance of success.

Choice of location.

Experience with settlement in the warm, humid tropics[69] indicates that the following principles should be given careful consideration before choosing the location for a community center:

1. Broken country is often preferable to flat, open country since it creates local air turbulences of value to human comfort, especially in a warm, moist climate. In the Markham valley, this could be achieved by locating habitations in the foothills adjacent to the main valley or on alluvial fans near the mouths of tributary valleys which serve as funnels for cool air settling down from the mountains at night. This will also tend to reduce glare, and in broken country the higher sites are also apt to be somewhat better drained.

2. The site or sites should have ready access to recreational

[69] See, for example, Douglas H. K. Lee: Physiological Considerations in the Development of Tropical Centres. Open Report No. 1, Fatigue Laboratory, National Health and Medical Research Council (Australia), 10 March 1945, pp. 3-4.

facilities in higher altitudes (3,000 feet or more) in the interests of mental and physical health. All parts of the Markham and upper Ramu valleys lie fairly close to the plateau, but some lie nearer than others to preferred locations for rest camps.

3. Priority of site should go first to hospitals; second, to the residential quarters; third, to educational establishments; and fourth, to administrative quarters.

4. Houses should be well-separated to permit free air movement and privacy, which tends to be destroyed by the open type of house construction best suited to tropical living. Irregular alignment is desirable, especially from the aesthetic standpoint.

5. Every advantage should be taken of altitude, consistent with other requirements. In the Markham and Ramu valleys this can best be accomplished by locating settlements near the apexes of alluvial fans or in hilly country such as is found a few miles northwest of Nadzab.

6. There is very little temperature difference between north-facing and south-facing slopes for the year as a whole in this latitude, but an east-facing slope is usually in shadow during the late afternoon and hence likely to be somewhat cooler for the day as a whole.

7. Shade trees are desirable if they are not too thick to cut out air circulation. Since they take years to mature it would be advisable to select a site near scattered trees or in semiopen groves.

8. Location near a spring or stream issuing directly from the mountains would be desirable from the standpoint of water supply. If a stream or shallow spring is to be used, its catchment basin should not be occupied by native dwellings or gardens, which would favor water pollution.

House construction.

In contrast to most European settlers in the tropics, the natives of the South Seas build houses that are remarkably well-adapted to local climatic conditions. The thatched roof, elevated floor, and open walls of the Samoan dwelling take every advantage of light breezes in a warm, humid climate. The Papuan house, with its higher, open end facing the prevailing wind and with its high-peaked roof for shedding tropical downpours, likewise represents a good adaptation. Highland natives of New Guinea commonly live in squat, round huts of wood, clay and thatch built close to the ground to keep out the chill night air.

The following principles of house construction [69] should be carefully studied and, where practicable, closely adhered to in the construction of settlers' homes in warm, humid climates such as are found in the lower elevations of New Guinea:

1. The roof should present the lowest possible angle of incline to the sun's rays. This will be achieved by having a fairly steep roof with the ridgepole oriented in an east-west direction in this latitude, where the sun is nearly overhead at noon. (If the long axis of the dwelling is north-south, half the roof will lie at right angles or nearly right angles to the sun's rays for a considerable period during the morning and the other half during the afternoon.)

2. The roof should present as good a reflecting surface as possible to the rays of the sun. Light-colored, metallic paints or whitewash are good reflectors.

3. Roof materials should have a high heat capacity to provide a minimum rate of heating.

4. Roof materials should possess a low rate of heat transmission. A thick roof favors this. If air pockets are included in the roof material, they should be so constructed that convection currents are at a minimum, i.e.: air spaces should be narrow and unventilated.

5. The inner roof surface, like the outer surface, should be a poor radiator of heat.

6. Glass windows are solar "heat-traps," passing short wavelength rays from the sun directly through to the inside (except in the ultra-violet frequency, which is only a small fraction of the incoming solar energy) and retarding the outflow of long wavelength re-radiation from within. Glass windows, if they are used at all, should be restricted to aspects of the building not directly exposed to the sun.

7. Outside blinds are more effective than inside blinds, if they are to be used at all.

8. Houses should have as many openings as possible (windows and doors) consistent with the need for protection against rain and insect pests.

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[69] For a fuller discussion, see Douglas H. K. Lee, *op. cit.*, pp. 5-6. See also by the same author: Physiological Principles in Tropical Housing. Dep't of Physiology, University of Queensland Papers, Vol. 1, No. 8, 1944, pp. 1-22. A Basis for the Study of Man's Reaction to Tropical Climates. *Ibid.*, Vol. 1, No. 5, 1940, pp. 77-78. Human Climatology and Tropical Settlement. John Thomas Lecture, Univ. of Queensland, 1946, pp. 30-31. (Unpublished manuscript.)

9. Screens and mosquito nets retard free air movement and should be used as little as possible in this area (the Markham and Ramu valleys) where air movements are ordinarily light. (This does not necessarily contradict No. 8.) Screens should be used on all doors and windows leading to the *outside*, but an aerosol mosquito "bomb" or a spray of DDT used occasionally on the inside of the house is an effective exterminator of insects and preferable to inside screens or the use of a mosquito net at night. If the outside breeze is light or the air is still, fans inside the house may be used to provide artificial air currents.

10. In a warm, humid climate it is desirable though not essential to have an electric fan in each room that is in use for several hours at a time, preferably the large, medium-velocity, overhead type which provides good air circulation without strong draughts. This is a relatively inexpensive and effective means of air conditioning if electricity is available, and does not produce extreme contrasts between indoor and outdoor temperatures conducive to rapid changes in skin temperature and consequent lowering of bodily resistance.

11. As far as practicable, rooms should be large and well-ventilated.

12. Sleeping quarters should be located and designed to provide maximum coolness at night, i.e.: exposed to local, nighttime air currents such as the down-valley movement of air from the mountains. The early part of the night should be given the most consideration in this respect, since that is the time when temperatures are highest and one is trying to get to sleep.

13. The living room should be designed and situated so as to be cool in the early evening when it is in greatest use.

14. The kitchen should be designed and located to be as cool as possible in the daytime, and should be equipped with either a portable or fixed overhead fan to remove heat and water vapor from the cooking area. Stoves should liberate as little heat as possible. A gas range is preferable to an open wood stove, and an electric stove probably comes as close as possible to the ideal, in this respect, although more expensive.

15. The design and furnishings of the interior of the house should require as little cleaning as possible, and should be made of materials not subject to the attack of termites, molds, and mildew.

16. Accessories in the kitchen and laundry should be located

conveniently to minimize the amount of moving about and handling required of the housewife.*

17. More than two years of living in the tropics and many conversations with life-long residents there have convinced me that comfortable living in tropical lowlands depends to a very appreciable extent upon two items: the fan and the refrigerator. The former provides respite from the heat after a long day's work, whether physical or mental, and the latter means cool beverages (milk, fruit juice, or water rather than whiskey in such a climate!) on warm evenings and an abundance of fresh, uncontaminated food. We in America are often inclined to take the refrigerator as a matter of course; in the tropics it is one of those modern inventions that make all the difference between living and enduring life.

18. Electric lights are not only superior to all other inexpensive types in supplying illumination, but, being usually farther removed from the person making use of them, also impart less heat. Electric lights run by small, inexpensive, gasoline-powered generators are in use today at various Australian outposts in New Guinea, and they served us faithfully and well at hundreds of bases in the Pacific during the war. Electricity, whether dependent on imports of gasoline from overseas, supplies of petroleum yet undeveloped in New Guinea, local coal deposits, or hydroelectric power, is probably one of the "minimum essentials" for successful large-scale colonization in any part of New Guinea.

A final word on general aspects of the housing requirements seems desirable. Both siting and construction should be planned in such a way as to offer maximum protection from the sun and maximum exposure to the wind. (Since rain falls nearly vertically here as a rule, we may assume that a watertight roof with substantial overhang is all that is required to afford protection from the rain.) Materials used in house construction should be resistant to the attack of termites (locally referred to as "white ants"), fungous growth, and mildew. Suitable timber is available locally and there is probably no shortage of building stone or materials for cement manufacture. Sand and gravel are abundant in the river beds, and limestone outcrops at frequent intervals on the south side of the Markham and Ramu valleys.

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* For the same reason, houses should be of single-story or "bungalow" type to eliminate stair-climbing. The argument that such houses are more expensive to heat does not apply here. They need be no more expensive to build or keep cool.

As to the cost of adequate housing, no reliable estimates are available or can be made at this time, and in any case they would vary widely depending on the extent to which local materials were used in place of imported materials, the amount of construction work done by settlers in place of imported white labor, the extent to which native labor might be expected to contribute, the size of the house and type of construction, the number and kind of household fixtures and appliances that are necessary or desirable, and many other variables. The natives are capable of putting up adequate temporary shelter in a short time in the form of pole frames covered with thatch and floored with bamboo, and can under proper supervision turn out in due time some fairly respectable pit sawn lumber, but durable, attractive houses will require modern sawmills and trained architects, carpenters and other specialists. If one hires a group of 10 or 20 natives to build a native-style dwelling, modified somewhat to meet the white man's basic needs, one can "get by" for as little as a few sea shells, some sticks of rope-twist tobacco, a little canned food, some cotton cloth, and other cheap trade articles. This is the way the Australians get their government lodgings and offices built on the plateau. But the results are far from satisfactory in the long-range view, and certainly not up to the minimum requirements or at least minimum expectations of prospective white migrants looking for a permanent abode.

SUGGESTIONS FOR PROPER CLOTHING

"The chief objection to heavy clothing" in a warm, humid climate, writes Lee,[79] an Australian physiologist, "is . . . its obstructive effect upon convective removal of air saturated with evaporated sweat." He continues, "Hence . . . light, porous, scanty, and loose clothing is to be desired. When exposed to the sun, however, some compromise is necessary to protect the body from heat gain by radiation, but this compromise must not trespass much upon convection. If half the body is protected from the sun by a light protective layer and ample ventilation provided by wide arm, leg, and neck pieces a satisfactory compromise should be secured. . . . The use of heavy underclothing . . . is generally to be discouraged . . . the use of light underclothing may be of advantage in soaking up

[79] Douglas H. K. Lee: A Basis for the Study of Man's reaction to Tropical Climates, *op. cit.*, pp. 76-77.

and offering for evaporation sweat which would otherwise have rolled off the body. The relative advantages of cotton and woollen underclothing seem to depend upon circumstances. Wool dries out less quickly than cotton, so that less rapid skin cooling and less marked reflex respiratory disturbances occur if the worker sits about in sweat-saturated woollen clothing. This slower drying would, of course, retard heat loss during the working period."

Price [71] quotes Yaglou to the effect that laboratory investigations show normal clothing reduces the cooling effect of wind by about 50 per cent, as compared with that which obtains when only light work trousers, socks and shoes are worn. He advocates stripping to the waist providing the temperature conditions do not exceed the limits at which air movement no longer cools the body, but heats it. Both Price and Lee minimize the importance of wearing headgear in a hot, wet climate, except when the head is exposed to the sun for several hours during the heat of midday.

In a more recent discussion of the clothing problem, Lee [72] emphasizes the value of durable, closely woven fabrics in reducing the incidence of malaria among Australian troops during the war, but adds that such clothing undoubtedly contributed heavily to the widespread occurrence of the so-called "tropical dermatoses" (skin infections) among these troops. This raises a question to which we would at present seem to have no satisfactory answer: is it better to wear a minimum of clothing in northeastern New Guinea and encourage rapid loss of body heat and a low incidence of tropical dermatoses or provide as complete coverage as possible and thereby protect the body from the attacks of malaria mosquitos or even more dangerous insect pests such as the mite that transmits the scrub typhus infection? The answer to this will depend on the risks of infection there, which we do not now know in detail. During my stay in New Guinea, at Nadzab and Hollandia but more especially at Biak Island, Owi Island, Noemfoor Island and Sansapor, we were encouraged — even ordered — to wear clothing impregnated with dimethylphthalate, and the prescribed army uniform included the "MacArthur shirt" which had extra flaps to cover the throat and wrists, thereby affording additional protection against the mites that spread scrub typhus. We were also cautioned to keep our

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[71] A Grenfell Price: *White Settlers in the Tropics*, Amer. Geogr. Soc. Spec. Publ. No. 23, New York, 1939, p. 224.

[72] Douglas H. K. Lee: Human Climatology and Tropical Settlement, *op. cit.*, p. 21.

trousers tucked into our boots whenever venturing into the kunai grass, brush, or forest. There is no doubt that scrub typhus is a serious disease and one that for a time caused great concern among medical officers and the high command in New Guinea. But many of the rank and file, when they thought they could get away with it, surreptitiously removed the extra short flaps or left them unbuttoned, and strongly objected to the impregnated clothing, which was heavier and less porous than the standard cotton uniform and hindered free air circulation about the body.

If the Markham and Ramu valleys are to be settled by white people, it is important that a satisfactory solution be found to this vexing problem. Perhaps the best "solution" is to wear as little clothing as possible during the day in cleared areas or indoors (except when exposed for several hours to direct sunlight) and at night when indoors behind protective screening, and eliminate or at least effectively control the anopheles mosquitos and the typhus mites by a vigorous attack upon their breeding places with spraying devices, by draining stagnant water, and by clearing the inhabited parts of the valley of undergrowth with tools and machines. It seems hardly possible that merely wearing protective clothing will be effective over a long period of time, and it will certainly add to the discomforts of life in a warm climate. Eliminating the vectors of disease, though expensive, seems the most effective way of dealing with the situation. These valleys, it is important to note, do not appear to be major foci of scrub typhus infection. The number of cases contracted there during the war was small by comparison with the number contracted on smaller islands off the northwest coast of New Guinea, and on the Vogelkop. The mortality rate, in any case, has been generally exaggerated. On Biak Island in July and August, 1944, it was only about one per cent of those contracting the disease (1,050 cases) and at Sansapor from the end of July to mid-September, 1944, it was about 3 per cent (out of 900 cases).[73] This disease, however, is not to be taken lightly. The average number of work-days lost per case (among U. S. troops in New Guinea) in mid-1944 was 80.3. A careful survey of the area here under consideration should be made by competent medical authorities prior to the establishment of settlements to determine the geographical distribution of the mite vector and the incidence of the disease as

[73] Office of the Surgeon: Essential Technical Medical Data. HQ, USASOS, 5 October, 1944.

well as the best means for control if it should prove to be a real danger.

TROPICAL DISEASES AND THEIR CONTROL IN NEW GUINEA

At the outbreak of World War II malaria had an unsavory reputation as the "world's greatest disease scourge." This reputation was upheld in 1942 and 1943, so far as American troops in the western and southwestern Pacific were concerned, by the terrible havoc wrought by malaria among our defending troops on Bataan (more than half at the time of surrender were weakened by malaria) and subsequently by severe outbreaks in the Solomons and New Guinea, where at one time several allied divisions were incapable of taking the field because of malaria relapses, and patients with this disease occupied 40 per cent of the field hospital beds.[24] The peak of infection among our troops in the Solomon Islands was reached in 1943, when the monthly infection rate on Guadalcanal reached 15 per cent. Among Japanese troops in the Solomons and New Guinea, especially in the period from early 1944 to the end of the war, malaria incapacitated entire regiments, and it is estimated that the overall incidence among Japanese troops after March, 1944 was 70 per cent. In the Bismarck Archipelago the malaria incidence among Japanese troops was 20-25 per cent a month, or put differently, if a unit remained in the area four to five months without replacements it could probably expect 100 per cent malarial infection. In New Guinea malaria was "almost universal" among Japanese troops in the last two years of the war, and records show that one hospital had a malaria *mortality* rate of 45 per cent.[25]

This grim situation was altered profoundly during the last two years of the war as far as American troops in the south and southwest Pacific were concerned. On Guadalcanal the monthly malaria infection rate fell from a high point of 15 per cent to about 10 per cent, at which it remained until hostilities ceased on the island. In the Central Solomons it never exceeded five per cent, on Bougainville it was about one per cent, and in the New Hebrides 2.5 per cent. In New Guinea we suffered heavily from this disease at first,

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[24] Lt. Col. O. B. McCoy, M.C.: Malaria and the War, *Science*, Vol. 100, No. 2607, 15 Dec. 1944, p. 526.

[25] Japanese Medical Problems in the South and Southwest Pacific, "Know Your Enemy" Series, 3rd Amphibious Corps, 25 Dec. '44.

but in 1944 and 1945 malaria was of less concern than several other infections, both as to number of cases contracted and the length of the convalescent period. The death rate was "low." [76]

Credit for this important decrease in the ravages of malaria in this theater of operations must go largely to our hard-working medical officers and malaria control units in the field, and to atabrine, the synthetic drug that largely and necessarily replaced quinine as a malaria-suppressive during the war. (Neither quinine nor atabrine is a malaria preventative, but promising leads toward the discovery of such a drug are said to have been uncovered as a result of wartime research.) The Army also had considerable success in reducing the number of cases of malaria at base installations by draining, filling or larviciding the breeding places of the malaria mosquito, screening of buildings, and spraying of insecticides. This required the combined efforts of many trained parasitologists, entomologists and sanitary engineers, as well as thousands of enlisted men and natives engaged in the physical labor connected with such anti-malaria measures.

Two important developments in wartime anti-malaria research were the invention of the aerosol mosquito "bomb," a one-pound cylinder containing enough pyrethrum insecticide to kill all mosquitos in 150,000 cubic feet of space, and the discovery of DDT. The former is used to best advantage indoors and will if properly used destroy all mosquitos within the dwelling. The latter is perhaps the most toxic substance yet discovered for mosquito control, and can be sprayed from a plane cheaply and effectively to destroy adult mosquitos and larvae in the breeding areas. It may also be sprayed on inside surfaces where it forms a residue that will kill insects lighting on treated surfaces as long as several months after application. It is claimed by Army medical authorities that "the world-wide postwar picture of malaria will be greatly changed by the advent of DD.T." [77] Some caution may be necessary in accepting this claim at its face value, however. Its toxic effect is not confined to mosquitos, and we lack proof as yet that indiscriminate spraying of the insecticide will not be toxic to useful plants in the areas sprayed, animals dependent on them for food supply, or essential microorganisms in the soil. It is one thing, moreover, to claim that "Our armies are demonstrating that white men can invade the

[76] *Ibid.*
[77] Lt. Col. O. R. McCoy, M.C.: Malaria and the War, *op. cit.*, p. 538.

tropics and conquer malaria," and "The world can look optimistically toward more effective malaria control in the postwar years,"[78] and quite another to prove that this could be done cheaply enough to render large areas of malarial country suitable for habitation by white people, or that stamping out malaria by such means will not at the same time result in the poisoning of valuable plants, insects and animals as has been claimed. We need much more information about the toxic properties of DDT before we can safely designate it as the "wonder drug" in malaria control.

Malaria is widely distributed in New Guinea except in the higher elevations, where it appears that the vector (*Anopheles punctulatus*) is not found above 5,000 feet elevation, and at or near that altitude only on the floors of some of the plateau valleys.[79] In 1940, from 14 to 19 per cent of all white hospital admissions in Papua and the Mandated Territory were for malaria and blackwater fever, and the rate among native admissions was from 25 to 30 per cent. In some regions almost 100 per cent of the natives have or have had malaria. The Markham and upper Ramu valleys, being better drained than most other parts of the lowlands, would seem to provide better opportunities for controlling this disease, although the vector is found throughout the region. Malaria probably *could* be stamped out in this area, and somewhat easier than in most other parts of the lowlands of New Guinea. But what would be the cost in human energy, time, materials and possible damage to plant, insect and higher forms of animal life? These are questions for which there is at present no satisfactory answer.

Some Australians long resident in New Guinea dismiss malaria as something that "everybody gets and nobody worries about." Others neither minimize its evils nor overemphasize them, but automatically reach for the quinine bottle when beset with recurrent chills and fever. Most of them seem to expect to get it sooner or later, and regard it much as we do colds or an attack of flu. Malaria, however, often leaves permanent marks on its victims, particularly females who may thereby be afflicted with serious complications in pregnancy.[80] It is one thing for a hardy Australian patrol officer, missionary, or prospector to shrug off repeated attacks of the in-

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[78] *Ibid.*, p. 539.

[79] Oral communication from John B. Mackay, Chimbu, New Guinea, Nov. 1944, in which it was stated that malaria was prevalent at close to 5,000' in the Chimbu area.

[80] Z. T. Bercovitz: *Clinical Tropical Medicine*, Chap. 10, pp. 135-185.

fection, knowing that he can return to a malaria-free country after his tour of duty with a good pension, and quite another thing for white women and their children to face when they know that New Guinea is the "end of the road." In the latter case some assurance must be provided that malaria is at least on its way to being eradicated.

Dengue (breakbone) fever is widespread in New Guinea and severe outbreaks of this disease have occurred in the gold fields of the Morobe District bordering the Markham Valley on the south. Natives seem to be largely immune to this disease, however, and it therefore appears that immunity can be acquired, which is not the case with malaria. Transmitted by mosquitos, it is not contagious. The mortality rate is less than one per cent, and then it is usually confined to the very young or to the very old who are already suffering from debility caused by other conditions. Mild cases require merely rest in bed and drugs to relieve muscular pains and headaches. Prevention in the form of drainage of stagnant water, larviciding, and the use of mosquito repellants is reasonably effective.[51]

Enteric diseases (typhoid, paratyphoid, bacillary and amoebic dysentery) are common in the more densely populated parts of New Guinea. The first two may be controlled by inoculations prior to arrival in infected areas and at intervals thereafter, while the last two can be prevented only by rigid control of the sources of food and water and adequate sewage facilities. Amoebic dysentery is the more virulent and destructive of the two types, but happily is of rather rare occurrence in New Guinea. Bacillary dysentery, although it often results in a high mortality among the natives, is not of very frequent occurrence among white people on the island and the mortality rate among whites is very low. During my first visit to the plateau of New Guinea in April, 1944, Major James Lindsay Taylor, then District Officer of the region, told me that thousands of natives were dying as a result of an epidemic of bacillary dysentery recently introduced to the area, and that the Government of New Guinea at that time regarded the epidemic as the major problem to be faced on the plateau, of greater importance than much-needed road construction, building of government offices, increased food production, improvement of air strips, survey of resources, or development of educational facilities. The natives had no contact with

[51] Z. T. Bercovitz: *Clinical and Tropical Medicine*, Chap. 23, pp. 305-317.

white men until about 15 years ago, and this was the first epidemic of dysentery on the plateau. The presence of the disease creates a problem in the prevention of contamination of food and water supplies. Natives would have to be kept out of settlers' gardens, and the catchment basins of streams or shallow springs used as a source of drinking water would have to be rigidly protected. Although some natives in this region have habits of bodily cleanliness that are above reproach, others apparently are not very discriminating and their personal habits by no means encourage a safe, potable supply of drinking water.

Hookworm disease is widespread among the natives and results in extensive soil pollution. A spot survey in 1920 suggested that over 70 per cent of the natives of the Territory of New Guinea were infected with this disease.

Influenza and pneumonia are endemic throughout New Guinea and at times have become epidemic. The mortality rate among the natives is high, probably due in large part to crowded living quarters and poor diet, but it does not appear to be exceptional among white people where a balanced diet and adequate housing facilities are available. Much the same appears to be true of tuberculosis.

No case of syphilis among either Europeans or natives was reported between 1936 and 1943, though isolated cases were reported prior to 1936. Two or three cases were reported during the war among plateau natives, probably as a result of contacts with allied troops stationed there. Gonorrhea, on the other hand, is common among the indentured natives, particularly those living near the coast or in the ports. Yaws (frambesia) is quite prevalent among native populations, and it is estimated that about six to seven per cent of the natives in the Mandated Territory are infected. One-third of all native hospital admissions are for treatment of the disease.

Scrub typhus has been reported from both the Markham and Ramu valleys, and from the gold fields at Wau and Bulolo. Although virulent, this disease is not common and has never assumed epidemic proportions in the region. Removal of the kunai grass, scrubby undergrowth, and ground cover in the rainforest will do much to eliminate the breeding places and assembly points of the mites responsible for transmitting this disease.

In 1939-1940 approximately five per cent of all European and 24 per cent of the native hospital admissions in Papua were for the

treatment of tropical ulcers (tropical sloughing phagedena). Probably bacterial in origin, the exact etiology of this disease is unknown. Its common occurrence among the natives of this area may be due largely to debilitation as a result of other chronic diseases and dietary deficiency. Skin infections are common among both white settlers and natives, and as many as 11.7 per cent of the Europeans and 33 per cent of the natives admitted to government hospitals have been treated for skin diseases. Scabies and head and body lice are almost universal among natives.[82]

Eye diseases are common, especially among the natives, where epidemic conjunctivitis is of frequent occurrence. Trachoma is endemic, although the incidence of the disease is not high.

Acute infectious diseases occur sporadically in both native and white communities in New Guinea. These diseases include chickenpox, measles, mumps, diptheria, whooping cough, cerebrospinal meningitis and poliomyelitis. Disastrous epidemics have broken out in the past among the natives in certain areas. Cholera, plague, rabies, yellow fever, relapsing fever, undulant fever, scarlet fever and smallpox were not reported in New Guinea between 1933 and 1943.

Leprosy, while not a common or widespread disease in New Guinea, takes its toll among the native population in parts of Papua and the Mandated Territory. There were about a dozen lepers in the hospital at Mt. Hagen on the plateau during my visit there in July, 1944, and "many more" in outlying native villages. At that time no effort had been made to segregate them properly from other patients, but it is my understanding that plans had already been drawn up at that time to establish a leper colony in a remote part of the Waghi Valley. The disease does not constitute a menace to white settlement if lepers are segregated in colonies of their own, since leprosy appears to be a disease that is only acquired after years of close contact with an afflicted person, and even after such long exposure it is by no means certain the disease will be contracted.

Malaria, scrub typhus, dengue fever, and various types of skin infections probably constitute the major disease hazards in the Markham and Ramu valleys, though by no means the only ones. Of these, malaria is on the whole probably the most serious, although scrub typhus may prove to be the greater danger in some localities

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[82] Medical and Sanitary Data in the Territory of Papua, Army Medical Bulletin No. 65, Jan. 1943.

and dengue fever appears to be a faster spreader. Scrub typhus is generally less common in this region, while the mortality rate from dengue fever is lower than that of malaria and the effects of attacks less damaging in the long run. Certain tropical skin diseases may also be serious and perhaps require temporary transfer of the patient to a cooler, drier climate, but they are seldom lethal.

READJUSTMENT OF WORKING SCHEDULES DESIRABLE

Some adjustment of the work schedule to compensate for local climatic disadvantages is probably desirable. The heavier physical tasks should be performed in the relatively cool early morning and late afternoon. Those who obtain their livelihood largely by mental work will also find these the best times of day to concentrate on that type of work and, in addition, that the evenings are more suitable than the midday period.

It would seem desirable either to shorten the working day to six hours instead of eight or more, or provide a two-hour "break" at midday for relaxation. This does not imply that a midday break should be devoted to a "sleeping siesta." There are cogent arguments against the siesta habit.[83] If the same or very nearly the same amount of work is to be done here as in cooler climates, the siesta interruption means that it is necessary to begin work early or work late in the day. The former means early rising and interruption of that part of the sleeping period which is most refreshing because it is then coolest. Working late on the other hand restricts the relaxation that is desirable before the evening meal, and the period that probably should be devoted to recreation. Also a sleeping period in the middle of the day means that each work-day must in a sense begin twice, and efficieney is lower at the beginning of a work period than after work has been in progress for a time. The midday sleep, moreover, is not very refreshing, for it is usually hot at that time and one often lies in a bath of perspiration. A rest period would seem to be desirable in the middle of the day, but not one devoted to sleep.

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[83] R. K. Macpherson: General Aspects of Tropical Fatigue as seen in RAAF Ground Crew, *op. cit.*, p. 7.

SOME ADDITIONAL CONDITIONS FOR SUCCESSFUL SETTLEMENT IN LOWLAND NEW GUINEA

Experience with European-type settlement and with military operations in continuously warm, humid climates appears to justify the following observations:

1. The lowland tropics on the whole are no place for the physically or mentally deficient. Only superior types of settlers, alert and aggressive, are likely to survive the test in the long run.

2. Community spirit and pride are essential. These may be stimulated by friendly rivalry between communities.

3. Recreation, both mental and physical, should be purposeful and a part of the regular routine of daily life. Idleness means self-destruction.

4. Recreational facilities in the cooler climates on the plateau or in the mountains on Huon Peninsula must be available to all at frequent intervals, and should offer enough variety so that everyone will find the mental and physical relaxation that appeals to him.

5. Leaders must be selected with great care, and they must be recognized in their respective communities as the *true* leaders, not just the favored persons.

6. Each individual must be employed in something he really wants to do, and not be required to do something personally distasteful to him, except as all must perform certain community duties for the common weal.

7. Settlers should be taught from the start to regard the region as their permanent home, and if they leave it temporarily for visits to other regions they should feel that they are going *away* from home and not *back* home.

8. The dangers of tropical diseases such as malaria, scrub typhus, skin infections, and enteric diseases should be made perfectly plain to every settler, along with the degree of success in their control that may be expected by making full use of the necessary prophylactic measures.

9. Personal hygiene must be stressed, not only for its value in preventing disease, but also for its moral value.

10. Both long range and short range objectives should be part of every settler's creed. He must be able to look forward to some lifetime goal, such as leaving his children with a valuable and mortgage-free property, or reasonable security in old age if sacrifices are

made in youth. But he must also have objectives from day to day and week to week, such as increased production, greater income, improvement of his house and land, better entertainment, improved communications with the outside world, better educational facilities, organized sports, community fairs, and the like.

11. Some form of control over the movements and activities of settlers may be necessary. Should and could a special form of citizenship be adopted to prevent or decrease the likelihood of a large scale exodus, especially of the younger generation, to the cities of the Australian mainland or elsewhere before the experiment has been given a fair chance? The Australian Government is unlikely to accept or support any scheme for migration and land settlement in New Guinea, furthermore, that does not provide safeguards against unfair competition with existing plantation, mission, trading or mining interests, and adequate assurances that settlers will not interfere with the administration's plans for the improvement of conditions of life among the natives on the island. Understandably they will tolerate no flagrant abuse of native rights, no brutal economic enslavement of natives under whatever guise or pressure, no alien political ideologies likely to threaten their own aims or policies in the region.

12. Settlers must be carefully chosen to insure suitable agricultural experience; continuity of interest in the project; cooperation within the group and with existing governmental agencies; and continuing pride in the new "homeland."

MARKET PROSPECTS

Local market.

The market in New Guinea for food products of local origin is decidely limited. Most of the natives are self-sufficient and the few who work for the whites and hence do not have an opportunity to provide directly for themselves obtain food in partial exchange for their labor. Their wants are few and they produce few articles of any significant trade value in the white man's economy. The Australians have as yet and for many complex reasons made relatively little progress toward educating and training the natives to higher standards of living, and it will probably be a long time before a market can be developed among them that will absorb more than merely a few manufactured "dime store" trinkets for ornamental

wear, sticks of black "rope twist" tobacco, paint pigment for smearing on their bodies, cheap cotton cloth, and mouth organs. Their villages are widely dispersed, difficult to contact inland from the coast, and rarely contain more than a few dozen or a few hundred inhabitants.

The white population of the Mandate before the recent war was only 4,500. Most of these people were either in the gold fields some 50 miles south-southwest of Lae, in coastal ports on the mainland of New Guinea which, with the exception of Lae, Salamaua and Finschhafen, are distant from the Markham and Ramu valleys, or in the Bismarck Archipelago. The white population normally obtains the bulk of its food from Australia, but some also comes from family gardens and a little from native gardens in the vicinity of white settlements, where there is any surplus. The white population increased very little in the decade before the war, except in the goldfields, and there is no indication that Australians will flock to New Guinea in large numbers now that the war is won. There is perhaps a limited market in the goldfields and ports for fresh meat (Australia exported £70,763 worth of meat to New Guinea in 1938-1939),[84] eggs and poultry, fresh fruit and vegetables of types not obtainable locally, coffee and tea, butter, cheese and milk, peanuts, and strawberries and other "temperate" specialties grown on the plateau. The prospects for developing a profitable outlet for farm produce in the existing centers of white population in New Guinea, however, are not very bright owing to their small size, wide dispersal, the lack of adequate storage facilities, and the difficulties and costs of transport of perishables over long distances to small markets.

The only local market of importance for some time to come, therefore, would seem to be in new settlements or in expansion of old settlements through grafting new colonies onto early roots. The size of this market would depend largely on the number of settlers permitted entry and the proportion of these who were in non-agricultural occupations. It is not likely that this would constitute an important outlet for surplus farm products in the early stages of development, which necessarily must be experimental and small-scale.

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[84] Official Yearbook of the Commonwealth of Australia, Canberra, 1939, p. 513.

Export markets.

Australia is perhaps the logical export market for New Guinea farm produce since it is the nearest country where millions of people with comparatively high standards of living are engaged in occupations other than farming. The east Queensland coast, however, is in some parts as well-watered as New Guinea, has soils that in places are probably equal if not superior in soil fertility to any of those in New Guinea, and lies a great deal closer to the large metropolitan centers of Brisbane, Sydney, and Melbourne. It also has acquired prestige in farm production and has established close ties between growers and consumers. It is unlikely that settlers in the Markham and Ramu valleys on the north side of New Guinea could compete successfully with Queensland fruit and vegetable growers in free competition in the mainland centers of population at the present time. Nor is it likely that they will be able to do so in the near future, since there is still considerable land of fair to good quality in southeast Queensland that can be converted from extensive forms of land use to intensive fruit and vegetable production if the market for these products expands beyond present capabilities of sources of supply. It is also unlikely that settlers in New Guinea would be permitted to engage in such competition, even if it were practicable, in view of the well organized and politically influential Queensland growers' associations.

There are, however, a number of products of tropical or subtropical origin that Australia imported from other countries in prewar years, and which Queensland does not (and perhaps cannot) produce in sufficient quantity or quality to satisfy the Australian market. These products are included in Table I, which indicates the source and value in pounds Australian (about $3.25 to the pound) of selected imports.

Some of these products, such as tea, rubber, copra, ginger, and coffee, have already been considered in an earlier chapter as possibilities for New Guinea. Some may be quite unsuited to production by a progressive white colony requiring machinery to replace hand labor to a large degree. Some may not be suited to local edaphic and climatic conditions in northeastern New Guinea. A few, however, may be worth further consideration and perhaps trial when more is known of the details of soils and climates in the Markham and Ramu valleys as a result of field and laboratory investigations. Similar consideration of the tropical products nor-

TABLE I

Some Imports to Australia from Tropical or Subtropical Countries (1938-1939)[85]

Source of Supply	Products	Value in £ (Australian)
Ceylon	tea	680,985
	rubber	170,076
	coir *	10,643
Fiji	copra	38,485
	molasses	14,743
	hides	4,045
Hong Kong	ginger	6,003
India	bags and sacks	2,058,216
	hessians	415,355
	hides and skins	202,630
	tea	69,173
	jute	46,489
	gums and resins	36,692
	nuts, edible	34,957
	mats, and matting	33,025
British Malaya	rubber (crude)	863,200
	latex	45,951
	sago and tapioca	34,778
	spices (unground)	29,733
China	tung oil	83,148
	tea	53,662
	rice	12,165
	ginger	12,084
Netherlands East Indies	tea	1,564,387
	kapok	218,849
	rubber (crude)	213,095
	hemp	142,386
	coffee	25,828
Philippine Islands	hemp	82,474
	timber	33,855
	hoods for hats	3,885
		£7,240,997 Total

* Fiber from coconut husks

nally imported by Europe and the United States may reveal additional crops suitable for production in New Guinea, although it is probable that most of them have either been tried out there and found unprofitable, or for other reasons are not worth consideration.

We cannot, perhaps, afford to be optimistic at this time regarding the opening up of large, profitable markets in eastern Asia during

[85] Official Yearbook of the Commonwealth of Australia, *op. cit.*, pp. 512-516.

the next few years or even the next two or three decades. Standards of living in the Orient range from dire poverty to extreme wealth, but the great majority of Oriental people live on small farms close to the borderline of subsistence and have little to exchange for the products of other countries, especially if those products are costly manufactured goods or high-priced raw materials for industrial consumption. There is, however, some hope that the picture may change in time. Japan, already partly industrialized and now dispossessed of its former colonies in the tropics, will require increasing quantities of food and industrial raw materials and will probably have to meet a substantial part of this need through increased imports from tropical sources. China, if peace can be restored in that strife-torn country, seems anxious to embark on a program of rapid industrialization that it has even been claimed "may within 25 years surpass that achieved by pre-war Japan"[86] and thereby create large, new markets for tropical products. And India, with its fast growing population of over 400,000,000, is already well started on a program of industrialization, and soon may become an even more important contestant in the worldwide struggle to obtain additional raw materials of tropical origin for the hungry maw of modern industry.

We cannot measure future marketing prospects solely by past performances. Here in the United States for example, more different kinds of food (not necessarily new food plants) have been added to our national diet in the past 25 years than our aboriginal predecessors on this continent added in 5,000 years of plant domestication history. Nor does there yet appear to be any limit to the variety of new industrial uses we can find for products of the soil. America, it is true, can for a long time to come rely if necessary or desirable upon what are as yet relatively undeveloped sources of food and industrial raw materials in tropical America. China may be able to provide for many if not most of its needs in the way of tropical products for some time through scientific development of its southern and southwestern provinces or by encouraging production in nearby tributary countries in southeast Asia. Where will Japan and India turn if their populations and factories continue to increase? Now denied the opportunity to expand their territory geographically, both these increasingly densely populated and grow-

[86] V. C. Juan: Mineral Resources of China, Economic Geology, Vol. XLI, No. 4, Part 2 (supplement), June-July, 1946, p. 400.

ingly industrialized countries must eventually, if they are to progress materially to any important extent, rely more and more heavily upon external sources of supply for certain foods and raw materials. World peace *requires* that such progress be encouraged and that essential products be made available. History provides no illustration to date of a country or people of like size and number that has been persuaded or coerced into accepting starvation or abandoning the path of industrialization.

Guaranteed Markets?

Settlers in northeastern New Guinea cannot be expected to "stand on their own feet" from the start, as pioneers in the past have often been able to do in many parts of the world, and survive for very long. They must be financed over a period of several years, at least until they are equipped to produce for export. It may be necessary to guarantee markets for exports in advance or when exportable surpluses begin to accumulate, as well as prices that provide a reasonable return (i.e., sufficient to stimulate further production) for the amount of labor and capital invested in production. Ultimately, it is to be hoped, such a settlement would be able to compete in distant or open markets without this support, relying instead on its own ingenuity, hard work, and experience as well as local physical advantages and favorable geographical position to keep up with other areas producing in competition. Without at least temporary guarantees of this sort, it is hard to see how any large scale, progressive, western, agricultural settlement in New Guinea could possibly survive the first few years, in view of the comparatively high initial cost of making the region livable, the need for repayment of loans, and the necessity of maintaining Western standards of living, if for no other reason.

CONCLUSIONS

The present state of our knowledge of New Guinea's agricultural resources and of our ability or inability to establish permanent, progressive, agricultural settlements and maintain Western standards of living in the warm, humid tropics, is insufficient to permit final judgment at this time on whether or not northeastern New Guinea is suitable for such settlement. Badly needed, for example, are: (1) more precise information on the character of the soils of

the Markham and Ramu valleys and their capacity to provide satisfactory yields of crops for an indefinite period of time without excessively costly applications of fertilizer; (2) a better understanding of the pathologic and physiologic effects of a continuously warm, humid atmosphere on white people; (3) a clearer definition of the present and future needs of the Melanesian natives in New Guinea; and (4) fuller knowledge of trends in world and regional demand for specific foods and industrial raw materials of tropical origin.

There are, however, good reasons for exploring more carefully the possibilities for settlement in northeastern New Guinea at this time.* This investigation can perhaps best be accomplished by detailed field and laboratory studies in New Guinea and Australia, analyses of pertinent marketing problems, and perhaps subsequently the establishment of a small trial colony sufficiently well-equipped to provide after a reasonable period of experimentation a fair estimate of the potentialities and limitations of the region. This area *seems* to be one of the most promising, agriculturally at least, in New Guinea. The natives have been unable to do much of anything with it, and a large proportion of the low country is practically uninhabited. The climate of the Markham and Ramu valley floors which constitute most of the region under consideration is warm and humid, though probably no worse than that of the Gulf Coast of the United States during several months of the year, that of the Cairns district in northeast Queensland, and that of Manila, Batavia or Singapore. Close at hand, moreover, are highlands where the climate is delightfully cool at all times and where rest camps and recreational facilities could be established for frequent use by settlers, whose permanent homes and farms would of necessity be restricted to the floors of the Markham and Ramu valleys at low elevations in view of the large native population in the choicer parts of the highlands. Grass-covered terraces at intermediate elevations and close to the sea-coast on the northeast side of the Huon Peninsula might also be considered as alternative sites for recreational facilities.

Nor are these the only advantages of the region. There are two good ports, much improved during the war, at Lae and Finschhafen,

* One illustration is the current problem of what to do with displaced persons in Europe, which now taxes the patience, intelligence, and resourcefulness of the United Nations organization to the utmost.

where several large, ocean-going ships can dock and unload at one time, and where storage facilities of a sort have already been constructed. What was once, and could be again, a good, two-lane, gravel highway, leads 20 miles up the Markham Valley to the eastern limits of the grasslands at Nadzab, and its repair and extension farther up the valley would meet no greater constructional problems than providing low bridges or fords over some of the wide, shallow, lateral tributaries of the Markham River. Hardwood timber of many varieties and potential uses is to be found in the lower Markham valley between Nadzab and Lae and in scattered stands elsewhere, and there are forests of "pine" at intermediate elevations on the mountain slopes. All of the region is well-watered and most of it is fairly well-drained. Drought does not occur, but there are occasional "dry" spells of definite advantage in cultivation and harvest. The nights in most parts of the valley west of Nadzab are cool enough as a rule to require use of a blanket in the early morning hours, and the mid-day heat is often tempered somewhat by light breezes and occasionally by overcast skies. Building stone appears to be available on the margins of the valley, and sand and gravel are abundant in stream beds. There are outcrops of limestone on the south side of the valley, some of which might prove useful as sources of agricultural lime and cement. There are no large native settlements on the grasslands to serve as foci of disease, and with reasonable precautions and treatment local supplies of drinking water could be safely used. There are rock gorges along some of the tributaries of the Markham and Ramu rivers that might eventually serve as dam sites and sources of hydroelectric power. Finally, we cannot afford to ignore the possibility of post-war expansion of markets for tropical produce in Japan, India and China as the populations of these countries continue to increase and as industrialization progresses.

On the negative side, there are several handicaps to be considered. New Guinea is off the beaten track of most Pacific trade. There are very few (almost none) of the amenities of civilization anywhere on the island. The nearest important market for tropical food products and industrial raw materials is in southeastern Australia two to three thousand miles away, and this market can probably be supplied as cheaply or more cheaply for some time to come by existing sources of tropical products or by the expansion and diversification of production in nearby Queensland if a closer source is preferred.

A lumber industry larger than that of the present time is hardly justified in northeastern New Guinea in view of the wide dispersal of valuable types of rainforest trees (and hence expense in extraction) and the relative inaccessibility of most of the pure softwood stands in the mountains. Tropical diseases, mainly malaria, scrub typhus, and intestinal disorders are endemic in the region, and, although temporary control over them was finally achieved there during the war, it was only accomplished through the expenditure of much time, energy and investment in equipment. To achieve comfortable living quarters and working conditions for progressive, skilled, western settlers in the lowlands would certainly require much study, careful, controlled experimentation, and added expense. The construction of access roads to farms on the valley floors and a road to the recreational centers in the highlands would entail a considerable outlay of capital, machinery, and labor. The development of a sufficiently large hydroelectric power plant to meet the electrical power needs of a large number of settlers would be a costly undertaking, as would also be the supply of permanent telephonic and perhaps radio connections with other parts of New Guinea and the outside world.

Among the many agricultural problems bearing on prospects for settlement in New Guinea, that could prove to be a critical or deciding factor in success and about which we have little knowledge at present, is the nature and extent of crop damage that may be expected from insect pests and fungous diseases in the Markham and Ramu valleys, and whether or not present control methods would be sufficient to keep losses within reasonable limits. During the war short-lived army farms in the region generally reported little damage of this sort, and on most farms very little use was made of insecticides and fungicides, which were usually unavailable. It may be, however, that continued cropping of the land would favor the spread of some of these pests and diseases, and that their suppression might entail unreasonable expense. New Guinea's isolation, on the other hand, might render control to some extent more effective, by making it easier to prevent the introduction of insects and fungi that so far have not reached the island. A recent newspaper item dramatically announced that giant snails (slugs?) were causing "tremendous crop damage" in New Guinea. How serious this particular problem actually is or may become I do not know, but in tropical Queensland agricultural

scientists of the Department of Agriculture and Stock and the University of Queensland, local experiment station personnel, and the farmers themselves have so far managed to come up with control measures that have proved more or less effective each time that a new disease or insect pest has brought threatened ruin. There seems to be no reason to suppose that northeastern New Guinea will provide insurmountable difficulties in this respect, although an entomological and microbiological study of the region would be highly desirable along with the soil surveys.

After further detailed, "on-the-spot" study of the prospects for settlement in New Guinea by specialists in all scientific fields bearing directly on this complex problem, if it should then be clear that there is need for sending additional settlers to northeastern New Guinea and that such settlement is permissible and practicable, it will probably be desirable to establish first a small trial colony fairly close to the war-time road terminus at Nadzab. If this proves successful after a reasonable period of experimentation, additional migrants may be brought in to take up land either in this area or farther west up the Markham Valley and eventually perhaps beyond the divide in the upper Ramu valley.

A reliable estimate of the number of people these valleys might support must wait until we possess more detailed knowledge of their soils, the crops that may be grown profitably, the proper ratio of subsistence crops to export crops and livestock in the economy of the region, the optimum-sized farm for this area, the skills and capabilities of the settlers, the degree to which farm machinery can or must replace hand labor, the availability of markets for the disposal of surplus production and sources for the purchase of goods unobtainable in New Guinea, and many other important conditions influencing the population carrying capacity of the land. We might point out at this time, however, that if the productivity of these valleys should turn out to be equal to that of parts of Bukidnon Province in Mindanao, which were examined by the Mindanao Exploration Commission in 1939, 40 or 50 acres of land (10 arable acres) per family may prove sufficient. On this basis there would be room for perhaps 12,000 farm families in the Markham and Ramu valleys, or about 60,000 people all told. How many more might be absorbed in non-farming occupations we have no present way of knowing, but if the local situation is at all comparable to

conditions in America and Australia it might run to a total figure of 300,000 or more.

Of one thing, at least, we can be sure. New Guinea is not a tropical paradise with "unlimited" agricultural possibilities, nor does it appear to offer any other easy and comfortable path to permanent prosperity. Native Melanesians may find it relatively easy to subsist in the more favored parts of the island, but a progressive Western people who wish to maintain a higher plane of civilization will find even the best parts of the island a tough frontier that will yield benefits grudgingly for a long time to come. The conquest of this frontier clearly calls for a tough, intelligent, and determined type of settler with either independent means of his own or heavy subsidization, for a time at least, by private organizations or governments. He must be prepared, furthermore, to spend his life in New Guinea, and not consider himself merely a sojourner there, marking time until the first opportunity presents itself to get to some metropolitan center of his own choosing in another, more "civilized" part of the world. Men and women of this breed are not common today, yet it is difficult to see how progressive communities can be established in northeastern New Guinea by people of lesser qualifications, even if they are equipped with many of the comforts and conveniences of Western civilization. New Guinea provides a challenge. Are there people of white or any other color who now or in the future can rise to meet it?

RECOMMENDATIONS

We are now in a position to present the following recommendations relative to future settlement in north-eastern New Guinea:

1. An approach should first be made to responsible Australian government officials to determine their government's present attitude toward future settlement in the Markham and Ramu valleys and limited portions of the adjacent plateau and/or Huon Peninsula. If the Australian government is willing to accept additional migrants, pertinent matters for further discussion will include the methods of selecting settlers, the number and types of settlers acceptable to Australia, the rate at which they shall be allowed to immigrate if detailed field and laboratory studies show that favorable opportunities do really exist, the types of occupations in which settlers would be allowed to participate, citizenship requirements,

guarantees to insure adequate protection of Australian and native interests, markets for exportable surplus commodities to be produced in the area, capitalization of new settlements, taxation, medical supervision and care, restrictions (if any) on movement or migration to other areas in the future, the degree to which settlers would be allowed or encouraged to participate in local and insular government, and educational methods, goals and facilities.

2. If the Australian government is favorably disposed toward proposals for such settlement in this part of north-eastern New Guinea, a team composed of Australian and American scientific personnel should be sent to the area to survey the resources and weigh the prospects more carefully than is now possible from a distance with our present limited knowledge of the region's assets and liabilities. This team should include at least one civil engineer, one medical officer whose specialty is tropical diseases and their control, a plant ecologist, a geologist, a soil scientist, and an agricultural economist familiar with both plantation agriculture and subsistence farming in the tropics. It should be provided with sufficient funds, freedom of movement, and equipment to make a thorough examination of the entire region, and should be prepared to stay in the area three months or more if necessary.

3. A climatological study of the region should be made, based on available weather data, our knowledge of soils and plants as indicators of climatic characteristics, and such short-range records of temperature, humidity and rainfall as it is practicable to gather at a number of carefully selected stations during the survey. This work should be systematically correlated with the work of physiologists who have investigated problems in human climatology especially as they relate to humid tropical environments.

4. Examination and mapping of the soils in the field should be followed by chemical and physical examinations of soil samples in the laboratory of an accredited institution such as the Waite Institute in Adelaide, and additional soil samples should be biologically tested in pot cultures to ascertain whether or not the soils are deficient in any of the important mineral "trace elements," and how they are likely to stand up under sustained cultivation.

5. A thorough study should be made of the crops already tried out at the agricultural stations at Sangan and Kainantu (in and near the Markham Valley, respectively) and others located in areas of similar climatic and soil characteristics, to determine which crops

are best suited to local conditions and appear to offer greatest promise both for subsistence and export.

6. If these various investigations show that conditions in the region are generally favorable for agricultural settlement by Western people using agricultural machinery insofar as possible to replace native labor, and if the need then exists for opening this kind of land for settlement, a trial colony small enough to be manageable and inexpensive yet large enough to provide a fair estimate of the prospects, should be established. The best location for such a colony would, on the basis of present "evidence," seem to be in the vicinity of Nadzab, to capitalize on such advantages as existing roads, proximity to a good port at Lae, and other facilities developed during the war, thus keeping the costs of experiment and trial as low as possible. An advance guard of construction workers should set up adequate though not necessarily permanent quarters for the families who would form the "pilot" or trial group. (It will be necessary to include women and children in the trial colony in order to provide a fair appraisal of the difficulties and opportunities.) Perhaps 50 or 100 families carefully selected for their agricultural experience, superior intelligence, cooperativeness, and willingness to put up with primitive conditions for a time at least, would be sufficient to insure a fair trial. They must, however, be assured of adequate financial backing throughout the trial period, proper technical supervision, ample machinery, tools, seeds, fertilizers, and insecticides, effective medical care, educational facilities, opportunities for a normal religious life, home entertainment, suitable clothing, properly designed and well-located housing, occasional brief rest periods in the cooler climate of the plateau or intermediate elevations on the Huon Peninsula, with facilities for participating in various sports (especially outdoor sports involving mild physical exercise), stimulating reading material, comfortable sleeping quarters, and good food. They should adhere to a carefully regulated work schedule suitable for a warm, humid climate, take some form of regular daily exercise, and be encouraged to improve and beautify their houses, farms and gardens as prudence allows and as their fancies dictate. Above all perhaps they should be selected for their proven demonstration of community spirit. They must be convinced that theirs is an important pioneering venture of widespread interest and possibilities. They must not be allowed to feel that they

are being sacrificed on the political altar as guinea pigs in a foredoomed experiment.

7. If and when a trial colony is established, a few well-chosen sites elsewhere in the region should simultaneously be equipped with the material means and personnel for conducting agricultural experiments designed to show, if possible, where additional settlements might profitably be placed in the future, and what are likely to be the best means for making a reasonably good living on the land in different parts of the valley floors and adjacent highlands. Such outpost personnel could be rotated at intervals with personnel at the base colony, to insure relief from isolation and prevent stagnation of interest, although this would not be so desirable from the standpoint of the continuity of experiments and standardization of scientific observation and recording.

8. If the trial colony should prove successful, and the strategically scattered experimental outposts show promising possibilities in one or more additional parts of the valleys, the original trial colony could be enlarged and its activities diversified, and a new frontier of settlement established in the area or areas that seem best suited for further development. This, however, would have to be preceded by road surveys and road construction from the site of the original trial colony near Nadzab to the new frontier, and the building of acceptable living quarters by construction gangs at these new sites. (The importance of providing suitable temporary living quarters for settlers' families prior to their arrival can hardly be overestimated, in this region especially. More than one migrant to the group settlement areas in southwestern Australia during the 1920's arrived at his new holding after a long, arduous voyage from England, took one look at the dense, uncleared forests and undrained swamplands or noted the conspicuous lack of a roof to cover him on his first night in the wilderness, and walked to the nearest settlement with no further interest in pioneer farming. Western migrants will probably expect and require more in the humid valleys of northeastern New Guinea.)

9. Finally, throughout the various stages of study and experiment all additions to our knowledge of the problems concerning and the prospects for the establishing of successful farming communities in this region, and all activities of the various groups directly concerned, should be reported in full to a board of impartial observers at regular and frequent intervals. The board should keep in close

touch at all times with field representatives of the survey teams and settlers, and perhaps also make periodic personal inspections of the trial settlements in order that it may be in a position to terminate, modify or expand the project when in its judgment it becomes advisable to do so. Such a board should include representatives from each of the countries directly concerned with promotion and administration of the settlements. Either individually or collectively the members of the board should have sufficient knowledge and experience in agricultural, political, legal, economic, social and educational fields to insure that their decisions will be in the best interests of all concerned. (Vested interests and the settlers' own chosen representatives could appeal decisions, suggest ideas and problems to be faced, or present evidence to the board for consideration at any time, though they should not be represented directly on the board.) This would serve to prevent the exploitation of the settlers in any way and at any time during the developmental stages of the project, insure protection of Australian and native interests in the region, allow for necessary reform or modification in practices and planning, and prevent a slow, insidious, and perhaps eventually uncontrollable deterioration in the situation of the new communities. The board's task, in brief, would be to:

(a) Decide whether or not such settlement is practicable and desirable when sufficient information is on hand to pass intelligent judgment.

(b) Orient and guide the activities of settlers (if the decision in (a) is affirmative) along lines that will be most profitable and satisfying to all concerned, at least until the settlements are self-supporting and well-integrated into the regional economy and political and social life of the area, and

(c) Initiate action to terminate or expand the settlements if and when it appears desirable to do so in the light of conclusive evidence of either progressive and unpreventable deterioration or greater opportunity, subject to the approval of the government of the host country and the governments or private interests of contributing countries, and having in mind the best interests of the settlers.

Appendix A

Subsistence Crops Suitable for Northeastern New Guinea *

Crop	Varieties Recommended **	Remarks ***
Asparagus	Connover's Colossal Palmetto	Could probably be raised in cool highlands Not grown anywhere in New Guinea at present
Beans (French)	Kentucky Wonder Brown Beauty Canadian Wonder Stringless Greenpod Snake (Vigna sinensis) Madagascar Blue Lake Stringless U. S. Refugee No. 5 Burpee Stringless G. P.	Growing period 6-8 weeks Estimated yield 2000-4000 lbs. per acre, depending on variety, etc.
(Lima)	Lima Henderson Bush	
Beets	Crosby's Egyptian Crosby's Early Wonder Detroit Dark Red	Growing period 10 weeks Best suited for highlands, but might do well in Gusap area in upper Ramu valley Estimated yield, 10,000 lbs. per acre
Cabbage	Henderson's Succession Drumhead St. John's Day Late Flat Dutch Golden Acre Early Ball Early Jersey Wakefield	Best suited for highlands Estimated yield, 20,000 lbs. per acre Growing period 10-12 weeks

* Data from various written field reports by agricultural specialists in the Australian and American Armies (U. S. Quartermaster Corps); oral communications from Australian and American military personnel in charge of army farms in New Guinea; and from personal observations made at farm sites and native gardens.

** Not all the varieties listed may prove suitable for any specific site in the area. Experience will show which are best. Those listed here include both Australian and American varieties.

*** Yield estimates are only rough approximations. Actual yield from any given site will vary considerably, depending on such controls as the variety planted, altitude, exposure to wind and sun, soil moisture and soil fertility, planting procedures, kind and amount of fertilizer used, number of cultivations, etc.

Likewise the growing period will vary somewhat from the estimates given here, for essentially the same reasons.

Comparisons between yields in New Guinea and, say, Iowa, would be misleading without further information based on field trials in northeastern New Guinea (Markham and Ramu Valleys). At this time perhaps all we can say on the subject is that our admittedly inconclusive data from farms which functioned for only a few months or a year or two in New Guinea suggests that with scientific methods of production the yields of food crops would approximate those obtained on good Iowa land, and in some cases might surpass Iowa yields, in view of the year 'round growing season in New Guinea and the possibility of taking two or three successive crops from the same plot of land during a single year under a program of rotation and balanced fertilization.

APPENDIX A, CONTINUED

Crop	Varieties Recommended **	Remarks ***
Carrots	Danver Long Chantenay Early Nantes	Growing period 10-12 weeks Best suited for highlands, but do quite well in lowlands if soil favorable Estimated yield, 10,000 lbs. per acre
Cauliflower	Benares Main Crop	Best suited for highlands
Celery	Utah	Best suited for highlands Difficult to grow
Chinese Cabbage	Chihili Wongbok	Easily grown in lowlands or highlands Estimated yield, 20,000 lbs. per acre Growing period 8 weeks
Cucumbers	Early Fortune White Spine Long green Crystal Apple Kirby's Stays Green Black Diamond Apple Tart	Will do well in lowlands or highlands of this area, though subject to mildew in wet soils or heavy rainfall zone near Lae Estimated yield, 6,000-8,000 lbs. per acre Growing period 8 weeks
Eggplant	Black Beauty	Growing period 14 weeks Estimated yield, 20,000 lbs. per acre Thrives in lowlands, where easy to grow
Endive	Broad Leafed Batavian Full Heart Green Curled	Not grown in New Guinea to my knowledge Suitable for plateau?
Herbs	Parsley (moss curled) Mint Thyme Marjoram Sweet Basil Sage	Possibly suited to both lowlands and highlands
Irish Potatoes	Irish Cobblers Bliss Triumph Katahdin Sebago Houma Carmen Scottish Triumph Satisfaction	Suitable for highlands (3,000-6,500 feet) Little grown in New Guinea Small, local market Estimated yield, 10,000-20,000 lbs. per acre Growing period, 13 weeks
Kohl-Rabi	Early Green Early Purple	Suitable for highlands
Leeks	Giant Musselburg	Not grown in New Guinea to my knowledge, but a possibility in highlands
Lettuce	Imperial 847 Mignonette Black Seeded Simpson Neapolitan	Lettuce will not head in lowlands, but produces good leaf Growing period 5-6 weeks Estimated yield, 20,000 lbs. per acre

APPENDIX A, CONTINUED

Crop	Varieties Recommended **	Remarks ***
Maize (Corn)	Funk's Yellow Dent Hickory King U. S. D. A. 334 Yellow Corn Australian Guam White Hybrid Golden Cross Bantam Golden Sunshine	Suitable for lowlands or highlands, but sweet corn best in latter Growing period varies with type, etc., but several varieties mature in 85 days or about 12 weeks in lowlands, somewhat longer in cool highlands Estimated yield, 8,000 lbs. per acre
Okra	Long Green	Like Chinese cabbage, eggplant, and snake beans, okra seems to thrive in lowlands wherever soils are reasonably good
Onions	Hunter's Winter Yellow Globe	Best suited for highlands Estimated yield, 6,000 lbs. per acre Growing period 16 weeks
Papaya	New Guinea Long Tom New Era	Common in native gardens up to 6,000 feet A very desirable tropical fruit that bears continuously for several years when mature Growing period 6-7 months
Parsnips	Hollow Corn Large Guernsey	Suitable for highlands Growing period 16 weeks Estimated yield, 8,000 lbs. per acre
Passion Fruit	*Passiflora edulis*	Suited for lowlands and highlands Makes delicious fruit drink
Peanuts	Virginia Creeper	Suitable for lowlands or highlands
Peas	Telephone	Grow well in highlands at 5,000-6,000 feet Growing period 10 weeks Estimated yield, 2,000 lbs. per acre
Pineapples	Smooth Cayenne Ripley Queen	Growing period 12 months (from rootstocks) Can probably be grown satisfactorily in parts of highlands and possibly in Ramu valley near Gusap
Pumpkins	?	Suitable for lowlands and highlands Produced well on American farm at Port Moresby in 1944
Radishes	Red Scarlet Chinese White Long Scarlet French Breakfast White Icicle	Suitable for lowlands or highlands Growing period 4 weeks Estimated yield, 10,000 lbs. per acre
Rock Melons	Yates Mildew Resistant Rocky Ford	Growing period 12 weeks Best suited to highlands, but can be grown in lowlands
Silver Beet (Swiss Chard)	Fordhook Giant Lucullus	Growing period 7-8 weeks Estimated yield, 12,000 lbs. per acre

APPENDIX A, CONTINUED

Crop	Varieties Recommended **	Remarks ***
Spices	Peppers (California Wonder) Nutmegs Cloves Mustard (Large Curled)	Can probably be grown satisfactorily for local consumption in many parts of northeastern New Guinea
Spinach	New Zealand Spinach Prickly Seeded Round Seeded	Suitable for highlands? A wild New Guinea spinach is used by the natives, but might not find favor with most white people
Squash	White Bush	Growing period 10-12 weeks Suitable for lowlands or highlands Estimated yield, 20,000 lbs. per acre
Sweet Potato	Porto Rico Nancy	Native varieties much larger but not very palatable to white people Growing period, 16-20 weeks Estimated yield, 10,000 lbs. or more per acre Will thrive in good soil up to 7,000 ft.
Tomatoes	Earliwinner Break O'Day Marglobe Ponderosa Marvena Pritchard Burwood Prize Red Marbio Potentate Pearsons Rutgers	Growing period 10-12 weeks Estimated yield, 8,000 lbs. per acre Do very well in both lowlands and highlands of New Guinea A dwarf, bush tomato grows in some parts of the region and might have local use
Turnips	Purple Top White Globe	Turnips will probably grow quite well in the highlands at 5,000-6,000 feet, and can probably be grown in some parts of the lowlands Growing period 7-8 weeks Estimated yield per acre, 12,000 lbs.
Watermelons	Sugar Stick Yates' Market Early Yates Tom Watson Hawkesbury Wilt Resistant Klondike R-7 Florida Favorite	Suitable for lowlands and highlands Growing period 12 weeks Estimated yield, variable, but probably 10,000 lbs. or more

Appendix B

Suggestions for Control of Insect Pests and Plant Diseases *

Crop	Insect Pest and Fungous Diseases to Which Crop is Liable	Treatment Recommended	Quantity of Dust Required per Crop per Acre (approx.)	Quantity of Spray Required per Crop per Acre (Approx.)
TOMATOES	Corn ear worm, penworm, tomato mites, target spot, Septoria leaf spot, Irish blight	Composite Dust [1] or combined spray [2] at 2-week intervals	1½ cwt composite lead, copper and sulphur dust	40 lbs. lead arsenate; 50 lbs. cuprox; 50 lbs. wettable sulphur
CUCUMBERS	Pumpkin beetle, leaf eating ladybird, onion thrips, red spider, powdery mildew, downy mildew.	Same as tomatoes	Same as tomatoes	Same as for tomatoes
ONIONS	Onion thrips	Nicotine dust [3] or nicotine spray [4] as required	½ cwt. nicotine dust (3%)	3 pints nicotine sulphate; 14 lbs. soft soap
PEPPERS	Flea beetle, leaf eating ladybird	Lead arsenate dust [5] or lead arsenate spray [6] as required	¼ cwt. lead arsenate dust (40%)	7 lbs. lead arsenate
PARSLEY	Leaf spot	Copper dust or copper spray as required	¼ cwt. copper sulphate dust (15% copper carbonate and 30% sulphur)	7 lbs. cuprox
LETTUCE	Downy mildew	Copper dust or copper spray as required	Same as for parsley	7 lbs. cuprox
SWEET CORN	Miscellaneous pests including corn borer	Not likely to require treatment on new land	—	—

Rate of application of dusts: 20-30 lbs. per acre.
Rate of application of sprays: 50-150 gallons per acre depending on age of crop.

* Compiled from various sources including field reports of agricultural specialists in U. S. Army Quartermaster Corps and studies by the Department of Agriculture and Stock, Queensland.

[1] Composite dust — 5 parts lead arsenate, 6 parts sulphur, 3 parts copper carbonate, 6 parts kaolin.

[2] Sprays include lead arsenate, wettable or lime sulphur, nicotine sulphate and soft soap, cuprox or equivalent copper spray.

[3] Nicotine (3%) dust in hydrated lime filler.

[4] Nicotine sulphate and soft soap.

[5] Lead arsenate dust = 40% lead arsenate in a kaolin filler.

NOTE — *Do not use sprays or dusts shortly before harvest (within one week) as some of them are toxic to human beings.*

Appendix C

Possible Cash Crops for Northeastern New Guinea *

Crop	Where Suitable	Remarks **
Cacao	low and intermediate elevations	Market chiefly in Australia? (Australia imports over 5,000 tons a year from Acera and West Indies)
Cashew nuts	low and intermediate elevations	Secret of India's virtual monopoly lies in technique of removing hulls by hand, and cheap labor. Could machinery be substituted? Edible nuts and fleshy fruit useful, the latter type for kind of wine similar to sherry. Possible substitute in area where grapes not grown. Begins to yield when 3 years old; full bearing at 5 years
Citrus fruits	intermediate elevations in highlands	Suitable from 2,000-6,000 feet elevation. Oranges, lemons, limes and grapefruit could be grown in the region. Market small and local Risk of loss from several enemies.
Coffee	lower and intermediate elevations in highlands	*Coffea arabica* from 2,500-6,500 feet *C. excelsa* or *C. robusta* below 2,500 feet. Can be grown on steep, rough land Small, local market; good market prospects in Australia?
Corn (maize)	up to 7,000 feet?	Can produce three crops in a year, but not continuously. Rotation and fertilizer required in continuous cultivation program. Market probably small and local. Soils must retain water fairly well or dry spells will retard growth
"Cube" root (Lanthocarpus sp.)	lowlands	Possibly better prospects than for derris root in rotenone insecticide industry; larger roots, easier to grind

* Sources include: *Report of the Mindanao Exploration Commission, New York*, 1939, pp. 20-34; *New Guinea Agricultural Gazette*, Vol. 4, No. 1, 1938, pp. 25-31; Klein, W. C.: "A Comparison in Colonial Development," *Asiatic Review*, Vol. 33, No. 115, 1937, pp. 566-580; and oral and written communications from several tropical agriculturalists in Australia and America.

** It seems highly probable that, for the region as a whole, economic and political considerations will prove of paramount importance in the selection of specific crops for export purposes. Physical limitations and advantages will influence *areas* of specialization with respect to commercial or cash crops within the general region, and to a large extent dominate the selection of subsistence crops.

APPENDIX C, CONTINUED

Crop	Where Suitable	Remarks **
		Gathered by natives in Amazon jungles Clones obtainable from Canal Zone? Export from Philippines was 700 kilos in 1934, 48,901 kilos in 1937 Market in Australia? U. S. A.? Europe?
Derris root	below 1,000 feet	Woody vine of Asiatic tropics Used in manufacture of rotenone, an insecticide Profitable if rotenone content is 10 per cent or more (can dilute as required) American market demands 5 per cent rotenone content
Gum copal	?	Resinous substance from various tropical rainforest trees, mostly confined to Dutch New Guinea. Prospects in Mandate? Used in paints, lacquer, linoleum, plastics Can suitable trees be propagated on mountain slopes in Australian New Guinea? Plantation-grown? Market in Australia, U. S. A.?
Ilang ilang (Cananquim odoratum)	?	Philippine tree, flowers of which contain an essential oil useful in compounding perfumes Does well under plantation conditions First flowers appear in 7th year
Kapok	low and intermediate elevations	Must compete with Javanese plantations Wide soil tolerance Market in Australia?
Lumbang	low and intermediate elevations	*Aleurites moluccana, A. Fordii* and *A. Montana* are best varieties Tree native to Philippines; nuts yield lumbang oil and oil cake. Oil used extensively in paints, varnishes and lacquers *A. Fordii* produces true tung oil Can be grown under plantation conditions Machinery for extraction not complicated or costly Species should not be grown in mixed stands Market in Australia, U. S. A.? Produces nuts in 3-4 years

APPENDIX C, CONTINUED

Crop	Where Suitable	Remarks **
Medicinal plants	Varied altitudes	No information available at this time on plants of possible value in New Guinea. Some useful Philippine plants that might be grown in New Guinea include *Hydnocarpus* spp. and *Pseudostyrax* spp. used to make Chaulmoogra oil for treatment of leprosy; *Sp.* Ignatius bean (*Strychnos Ignatii*) for making strychnine; *Alyxia* sp. *Donax* sp. and *Lagerlroemia* sp. for treatment of snakebite and insect bites; *Picus* spp. and *Euryale* sp. for treatment of Rheumatism; and *Orthosiphon aristatus* for treatment of troubles of the urinary tract.
Peanuts	Low and intermediate elevations	Costs of production low if machine methods used. As a legume, is a good soil renovator Turned under, makes excellent green manure Hay makes good cattle feed Enemies controllable so far as known Varied industrial uses Market in growing industrial areas of Far East and Australia?
Pili (*Canarium* sp.)	†	Pili nut nutritious and delicious Now exported to U. S. A., where demand might be increased with familiarity Potential market in Australia? Probably suitable for plantation conditions Crop obtainable in 5-6 years
Ramie	below 2,000 feet	Takes 8 months to mature from seed cuttings Subsequent crops cut every 2 or 3 months If soil not well supplied with plant foods, good results require fertilization Fiber claimed to be 8.5 times stronger than cotton; six times stronger than silk; four times stronger than flax or hemp; parachutes made from it six times stronger but weigh half as much as materials used prior to 1939; will not mildew or rot

APPENDIX C, CONTINUED

Crop	Where Suitable	Remarks **
		and may be stored indefinitely; ropes, fishing lines, nets and sails will withstand 75-100 years of hardest wear and tear; fabries are cooler than cotton and thinner than linen; makes good filter cloth in air conditioning apparatus; has many other industrial uses Competition from synthetics like nylon and rayon?
Rattan	low and intermediate elevations	Climbing palm of genera *Calamus* and *Daemonorops*. Stems used for wickerwork, chairs, chair seats, cordage, etc. Market for inferior grades in China Grows wild in rainforest. Suitable for planting on steep, rough slopes?
Rice	low elevations	Upland type better quality but lower yield Lowland flood plains suggest possibility of machine cultivation, as in Louisiana Are soils suitable? Market in Japan and China? New Guinea? (1,500 tons of rice flown from Lae and Salamaua to goldfields near Wau and Bulolo each year. Cost £18 per ton in Salamaua and £37 per ton in Wau) Tractors and combines could be communally owned and operated, if rice fields contiguous Glass can be made from ash of hulls; pressed wall board from hulls. Other by-products: rice bran, an oil rich in vitamins, sugar and vinegar
Roselle (*Hibiscus Sabdariffa*)	?	East Indian annual herb. Calyxes are used for making tarts, jelly, and an acid drink Market for jelly in Australia?
Rubber	low and intermediate elevations	Large, potential overproduction? Market in Australia if industry can compete with high-yielding Malayan and N. E. I. plantations and synthetic rubber High yielding clones available from Goodyear plantation in Zamboanga, Mindanao? (if not from N. E. I. and Malaya)

APPENDIX C, CONTINUED

Crop	Where Suitable	Remarks **
Sesame	Up to 6,000 feet	Oil used in cooking; obtained from Sesame seeds Seed and oil cake used in making candies and pastries
Sisal hemp	?	Possibilities in new varieties of superior quality and yield Are soils of this region suitable? Market in Australia?
Some highland specialties for small, local markets, such as goldfields (Wau-Bulolo), Lae, Madang, Port-Moresby	3,000-6,000 feet	Strawberries Irish potatoes Bermuda onions Head lettuce Cabbages Green peas Celery
Soy beans	up to 6,000 feet	Produce oil and oil cake, sauce, etc. Varieties from Siam and South China might do well in New Guinea Two or three varieties do very well in Philippines if soil first inoculated with proper bacteria Varied food and industrial uses Market in central and South China? Japan? Australia?
Tea	intermediate elevations	In highlands from 3,000-5,000 feet Market in Australia chiefly; small local market in New Guinea
Tobacco	up to 6,000 feet	Small local market for high grade types but low grade ''rope-twist'' important in native trade and wages. (126 tons imported to Australian New Guinea in 1934-1935). Market in Australia? *Nicotiana rustica* used for conversion into nicotine sulphate, an important insecticide. Prospects in New Guinea?

Appendix D

While we have no reliable, detailed climatic knowledge of northeastern New Guinea, which would permit us to draw final conclusions at this time regarding its habitability from the climatic standpoint, we are not without what might be called "suggestive evidence" insofar as Lae and Nadzab in the southeastern part of the Markham Valley are concerned. Tables and graphs showing temperatures, rainfall, relative humidity, and wind velocity and direction for these two places in New Guinea and for other tropical stations scattered throughout the Pacific region appeared recently in the U. S. Army Air Technical Service Command's "Tropical Deterioration of Air Force Materiel and Equipment." (Wright Field, Dayton, Ohio, 1946, pp. 12-15.)

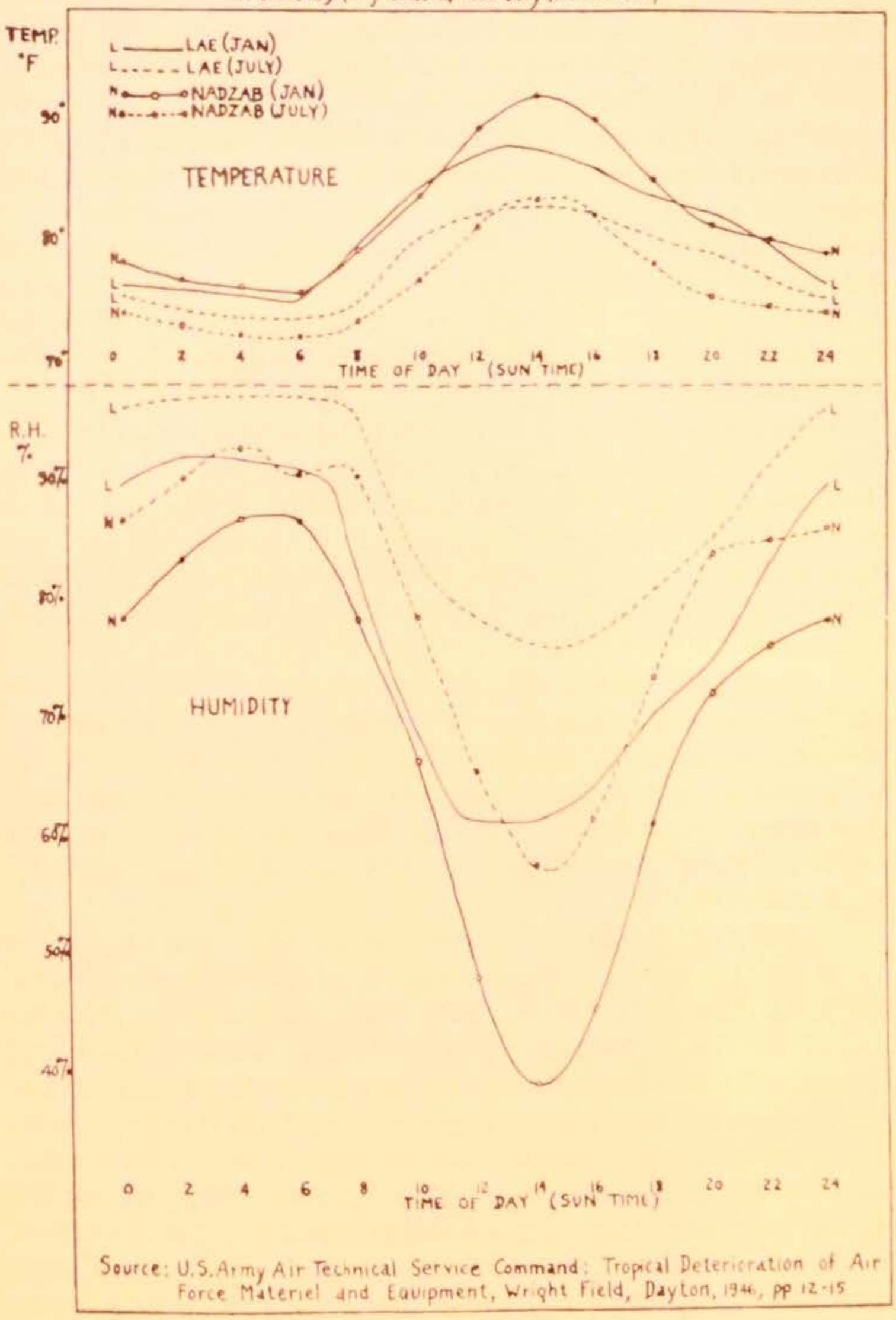
The graph included in Appendix D is based on a series of graphs appearing in the above report of the Army Air Forces, and shows the diurnal march of temperatures and humidity at Lae and Nadzab in both "wet" and "dry" seasons, for the months of July and January, respectively. Analysis of these curves, and of other comparative data in the Army Air Forces' report, suggests the following:

1) The Nadzab area is slightly warmer (thermometrically) than the Lae area during the middle of the day, in both the wet and dry seasons, has about the same night temperatures during the dry season and is slightly cooler in the wet season. These variations are probably due to differences in cloudiness, proximity to the sea, effects of land and sea breezes, and possibly topography and vegetation.

2) Although Nadzab is slightly warmer than Lae during the middle of the day, the relative humidity at Nadzab is considerably lower than that at Lae during those hours, and somewhat lower the rest of the time. Thus the "sensible" temperature at Nadzab (a function of both temperature and humidity) is lower than that at Lae much of the time, and the degree of discomfort arising from the performance of manual labor, especially during the heat of the day, would be less at Nadzab. It is probable, furthermore, that farther up the Markham Valley toward Gusap, where the land is higher, sensible temperatures are lower than at Nadzab. From the climatic standpoint alone, therefore, it would seem to be desirable to locate settlements well inland from Lae, between Nadzab and Dumpu.

3) The climate of the middle and upper parts of the Markham

DIURNAL MARCH OF TEMPERATURE AND HUMIDITY AT LAE AND NADZAB, NEW GUINEA
in January (dry season) and July (wet season)



Source: U.S. Army Air Technical Service Command: Tropical Deterioration of Air Force Materiel and Equipment, Wright Field, Dayton, 1946, pp 12-15

and Ramu valleys is no worse, and probably somewhat more comfortable, than the climate of Suva in Fiji, Manila in the Philippines, Rangoon in Burma, or Port Moresby in New Guinea, where small colonies of white people have been established for many years. It must be remembered, however, that these whites do not, as a rule, perform manual labor. Whether or not they would be better off or worse off if they did is still a moot question, although wartime observations and research in different parts of the tropics suggest that the right amount of such work, performed in the right way at the right time, is desirable from the health standpoint.

4) It would be quite misleading, on the basis of such short range climatic data and other sources of information now at hand, to attempt to make out a case for the "attractiveness" of the climate of the Markham and Ramu valley floors. Everything points to the relative "unattractiveness" of the climate in the lower elevations, as far as most Western peoples are concerned. But that is no sign that it is "intolerable," especially if we consider the possibilities for air conditioning, the opportunities for spending rest periods in cool mountains close at hand, and other ways of minimizing the unpleasant aspects of lowland, tropical climates.

Appendix E

Weed Control

A recently published article in *Science* (A. S. Crafts: "Weed Control in the Tropics," Vol. 107, February 20, 1948, pp. 196-197) brings out the following points about weed control which may help to open new horizons for agriculture in New Guinea:

1) The use of cheap hand labor for hoeing weeds is traditional in the tropics, but chemical treatment is now being given increasing attention. The 2, 4-D herbicides have the advantage of low cost and great effectiveness, and provide opportunities for conserving labor.
2) One disadvantage of their selectiveness is that they are nontoxic to grasses, especially coarse, vigorous, tropical grasses. These may, however, be controlled with an oil emulsion contact spray having the formula: medium gravity highly aromatic oil, 30 lbs.; pentachlorophenol, 2 lbs.; Oronite wetting agent, 2 lbs.; and water, 95 gals.
3) This spray emulsion will kill all green vegetation, but not cane, coffee, pineapple, or bananas if kept off their leaves while applied around bases.
4) The formula may be modified to suit varying conditions of weed growth. If grasses are coarse and mature, the oil concentration may be increased to 45 lbs. or more. Alternatively the formula's lethal power may be increased by decreasing the proportion of water in the formula.

The significance of such new developments as far as New Guinea agriculture is concerned is obvious. In most parts of the lowlands there is a critical shortage of native labor for working existing plantations. Extension of agricultural activities there on any considerable scale would require either imported (coolie?) labor or labor-saving devices or techniques which can take over effectively the native's role in local commercial economy.

PLATE III

Fig. 1 Native-built "jeep" road in the Waghi valley between Kerowagi and Mt. Hagen, New Guinea. Elevation about 5500 feet. Roadside plantings are mostly species of the genera *Croton* and *Crotalaria*. Mountains in the distance rise to about 12,000 feet.

Fig. 2 Combination suspension and trestle bridge under construction by natives on the new jeep road between Kerowagi and Mt. Hagen. River is the Waghi, which drains eastward and southward into a tributary of the Purari.

Fig. 3 Native-built "jeep" road and covered bridge on the interior plateau of New Guinea near Mt. Hagen. The only tools used in such construction are pointed or flattened sticks and stone axes. During construction the natives swarm like ants over the countryside and a road emerges in an incredibly short time. Unsurfaced, these roads are good in dry weather but slick after heavy or prolonged rains.

Fig. 4 "Corduroy" road built by U. S. Army Engineers across swampy tract in the lowlands of northeastern New Guinea. Such roads, designed for temporary use, are rough at best and difficult and costly to maintain. (U. S. Army Signal Corps photo)

Fig. 5 Suspension footbridge built by U. S. Army Engineers across a lowland stream in New Guinea. Materials consist of logs from the rainforest, steel cable, rope and sections of pierced steel plank ordinarily used for surfacing airplane runways where the ground is soft. (U. S. Army Signal Corps photo)

Fig. 6 Timber trestle bridge over deep ravine on a section of the two-lane, all-weather highway built by army engineers early in World War II across the Owen Stanley ranges between Port Moresby and Buna, New Guinea. Roads of this type are difficult, costly and time-consuming to build in the mountainous country, but will stand a great deal of punishment. (U. S. Army Signal Corps photo)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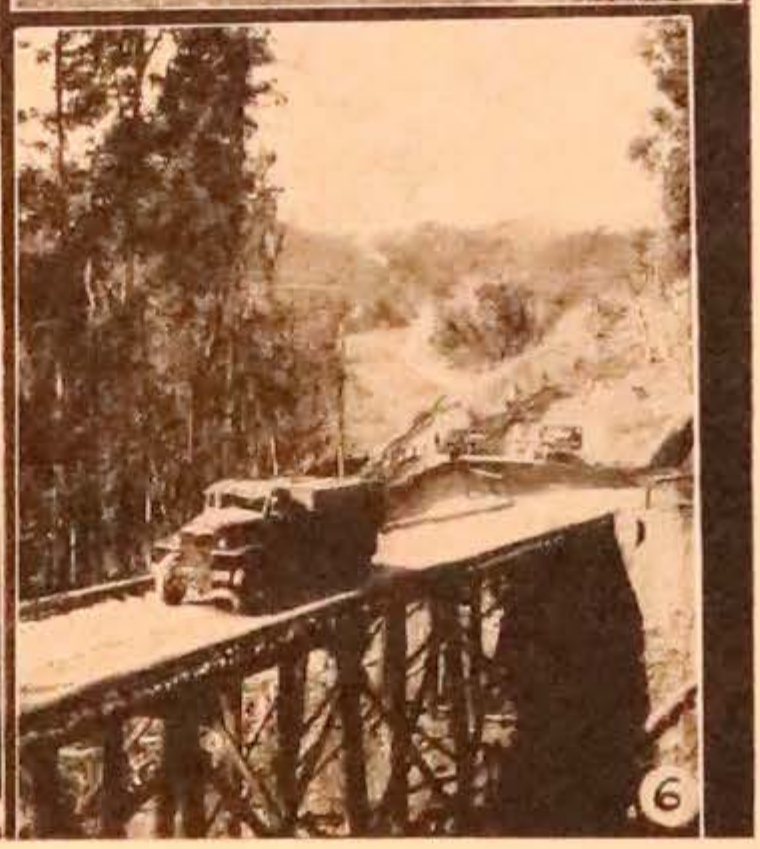
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PLATE IV

Fig. 7 Native village strung out along a ridge crest in the Waghi valley about ten miles west of Kerowagi. Houses are made of logs, poles, grass thatch and woven bamboo mats. Smoke in the distance comes from fires set by natives to clear patches of grassland for planting gardens.

Fig. 8 Group of natives and dairy herd at Mt. Hagen, New Guinea. Cattle thrive on the lush, green pastures here, more than a mile above sea level in a bracing atmosphere. These cows were not in milk at the time the photograph was taken, however. Note the large heads, deep chests and muscular arms and legs of these natives, typical of tribes in the Waghi valley. Fifteen years ago headhunting was their favorite outdoor sport and some tribes were not above occasional cannibalistic feasts.

Fig. 9 Australian headquarters at Garoka, New Guinea. Buildings are all of native construction. These houses are easily and quickly built from local materials, comfortable, keep out rain and wind as a rule, and are not unattractive, but they are not long-lived and can be improved upon if desired.

Fig. 10 Native "police-boys" playing a fast, rough game of soccer in bare feet at an elevation of 6,000 feet on the floor of the Waghi valley at Mt. Hagen, New Guinea.

Fig. 11 Australian administrative headquarters at Mt. Hagen, New Guinea. Elevation about 6,000 feet. Here one can drop out of the sky onto a short but good landing strip, lunch on roast pork, green peas, corn-on-the-cob, and strawberries with cream, and spend the afternoon knocking golf balls about, playing tennis, or prowling among native villages where stone age culture still prevails — all within seven degrees of the equator! Days are mostly sunny and mild, but at night four or five blankets are welcome. (Courtesy of the *Geographical Review*, American Geographical Society of New York.)

Fig. 12 Native labor force strung out along a road under construction on the plateau of New Guinea between Kerowagi and Chimbu. Tools are primitive but the men are muscular and energetic, and there are plenty of willing hands.


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PLATE V

Fig. 13 Natives, Australians and Americans all show curiosity as the first "jeep-plow" combination makes its appearance on the plateau alongside the Garoka air strip. Some thought the jeep couldn't drag the discs through the heavy clay soil, but . . .

Fig. 14 The jeep proved its mettle and easily pulled the plow. Turning the tough sod is hard work for natives with crude hand tools — much simpler and faster with even such light farm equipment as a jeep and small disc plow. This land was being prepared for vegetables in mid-1944 for shipment by air to Australian and American units in the Markham valley to the east.

Fig. 15 Air view of native gardens in the vicinity of Bena Bena. Individual gardens show great care and regularity in their layout, especially those that have an intricate pattern of intersecting drainage ditches. Land between the cultivated patches has been cropped many times before, and will be cropped again within a few years as the native farmers rotate their fields instead of their crops. (U. S. Air Force photo)

Fig. 16 The ancestors of the U. S. Air Force Colonel at the right passed out of the New Stone Age several thousand years ago, but his friend in the picture proudly and happily continues his Neolithic ways. Here he shows the Colonel what the well-dressed "luluai" or village chief in the Waghi valley will wear. Head and body ornaments are mostly of imported shell or local bone, the arm bands, leg bands and lower body covering are of woven grass and bark, while the headdress consists of cassowary plumes. The curved shell on his forehead indicates lofty stature in his village while wealth is shown by the five "gold-lipped" shells suspended from his neck — each of which is worth a pig or perhaps a not very attractive, amorous or hard-working bride.

Fig. 17 The round, metal, Australian army insignia on the forehead of the man in the foreground signifies that he is recognized as a village leader. He may give away all his material wealth to enhance his prestige some day, but he is not likely to part with that cheap, tarnished, metal button as long as he can wield a stone axe, spear, or bow and arrow! The shell ring on the forehead of the man at the right indicates that he is the "boss boy" of a work crew.

Fig. 18 Accidents like this will happen in mountainous terrain in New Guinea, where air strips are short and often have considerable slope, where the grass surface is very slick when wet, where visibility is often poor over the ranges, where pilots are inexperienced and most maps quite inaccurate, where high altitude means less buoyancy and where gasoline reserves may be used up trying to find a hole in the clouds. Happily our party of eight walked away from this crackup without serious injury, after overshooting the Kerowagi landing strip.

PLATE VI

Fig. 19 A wide strip of land next the Garoka air strip is plowed and ready for harrowing and planting. This day's work by one man and some light machinery would have taxed the capacities of several hundred natives working at full speed from dawn to dark.

Fig. 20 Garden produce (corn, marrows etc.) piled up alongside the air strip at Mt. Hagen, awaiting air shipment to Nadzab in the Markham valley 180 miles to the east and more than a mile lower down. A wide variety of fruits and vegetables of excellent quality was produced here during the war. This was the most productive garden on the plateau, and a favored port of call for air crews out for sight-seeing or souvenir hunting. Rarely were they turned away without a cargo by the Australian officer in charge, who knew what eating canned and dehydrated rations for months on end can do to a man's morale. (Courtesy of the *Geographical Review*, American Geographical Society of New York)

Fig. 21 Coconut plantation on the northeast coast of New Guinea, typical of many that fringe parts of Papua and the Mandated Territory. In New Guinea I saw no evidence of interplanting of crops like tomatoes and potatoes with coconut trees, as is common in Puerto Rico where pressure on the land is greater due to a high population density. Copra (the dried meat of the coconut) and gold paid New Guinea's way before World War II, but neither provides security and wealth to most planters and miners, who are hard put to "make a go of it." How much and what kind of diversification can the New Guinea economy support, if any? (U. S. Army Signal Corps photo)

Fig. 22 Natives tying tomato vines on poles in Captain Shlimovitz' fifteen-acre vegetable garden in the upper Ramu valley near Gusap, New Guinea. Good yields of a variety of crops were obtained by those who inherited the garden when the unit which started it moved out unexpectedly. The soils on this alluvial plain are excellent for vegetable growing, being deep, rich loams or clay loams high in organic content, which show little tendency to puddle when wet or form clods when dry. In pH they are neutral to slightly acid, for the most part.

Fig. 23 Captain Shlimovitz, who started the fifteen-acre garden near Gusap with a tractor, a plow, about a dozen natives, an American Sergeant, and some vegetable seeds of dubious origin, with some baskets of okra and beans from the first harvest. "Slim" moved on before he himself benefited much from his project, but he left behind a lot of "G. I." good will and he showed what could be done with land around Gusap, given a little machinery, a few helpers, and a good deal of enterprise.


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PLATE VII

Fig. 24 Clearing rainforest or "jungle" with bulldozers on Espiritu Santo in the New Hebrides, the first stage in the development of a large, modern truck farm there in 1944. The trees, though large and tall, have rather shallow root mats and yield — grudgingly in some cases — to the 'dozer blade of a big "cat." This is slow work and in the Markham and Ramu valleys, fortunately, grassy savannas render the task of clearing much easier. (U. S. Army Signal Corps photo)

Fig. 25 A tractor and plow easily tear up the thick, coarse, tropical grasses and their tough root mats in an old native clearing on Guadalcanal Island in the Solomon group, in the process of developing a truck farm of over 1000 acres to supply fresh vegetables to military personnel in the area (1944). This rich black clay loam derived from volcanic waste yielded three successive corn crops in one year from the same piece of land without the addition of fertilizer! Alluvial soils in parts of the Markham-Ramu valleys of New Guinea are similar in color, texture and depth, and therefore invite further exploration and experimentation. (U. S. Army Signal Corps photo)

Fig. 26 Natives planting corn in the Service Command garden, Matanio River Farm, Guadalcanal. (U. S. Army Signal Corps photo)

Fig. 27 Same, close-up. Older planting of corn in background. (U. S. Army Signal Corps photo)


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PLATE VIII

Fig. 28 Knowles Ryerson (at right), Dean of the Agricultural College of the University of California at Davis, inspects an ear of corn on the Malimbo River Farm, Guadalcanal. This corn, a hybrid type suited to the warm, humid tropics, was relished by military personnel in the area, and yields, at least during the first year of operations, were comparable to those obtained on good Iowa farm land. (U. S. Army Signal Corps photo)

Fig. 29 Victory garden planted by a Quartermaster unit in the rainforest on Bougainville Island in the Solomon group. Rich, volcanic soil coupled with plenty of moisture and the right amount of sunlight favored the growth of a fine crop of lettuce, tomatoes, radishes and other vegetables at this site, which also, fortunately, lay concealed from the muzzles of Japanese field pieces high on the mountain slopes to the east overlooking this part of the "Torokina Perimeter." (U. S. Army Signal Corps photo)

Fig. 30 Native laborers tying tomato vines to stakes in a garden on Bougainville in 1944. Volcanic soil and rainforest cover. (U. S. Army Signal Corps photo)

Fig. 31 Cacao plantation on Espiritu Santo island in the New Hebrides group, similar to plantations in parts of New Guinea such as the Madang region north of the Ramu valley. The industry is being revived in New Guinea at present. (U. S. Army Signal Corps photo)