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SOILS AND AGRICULTURAL DEVELOPMENT OF EASTER ISLAND (HOTU-MATUA)

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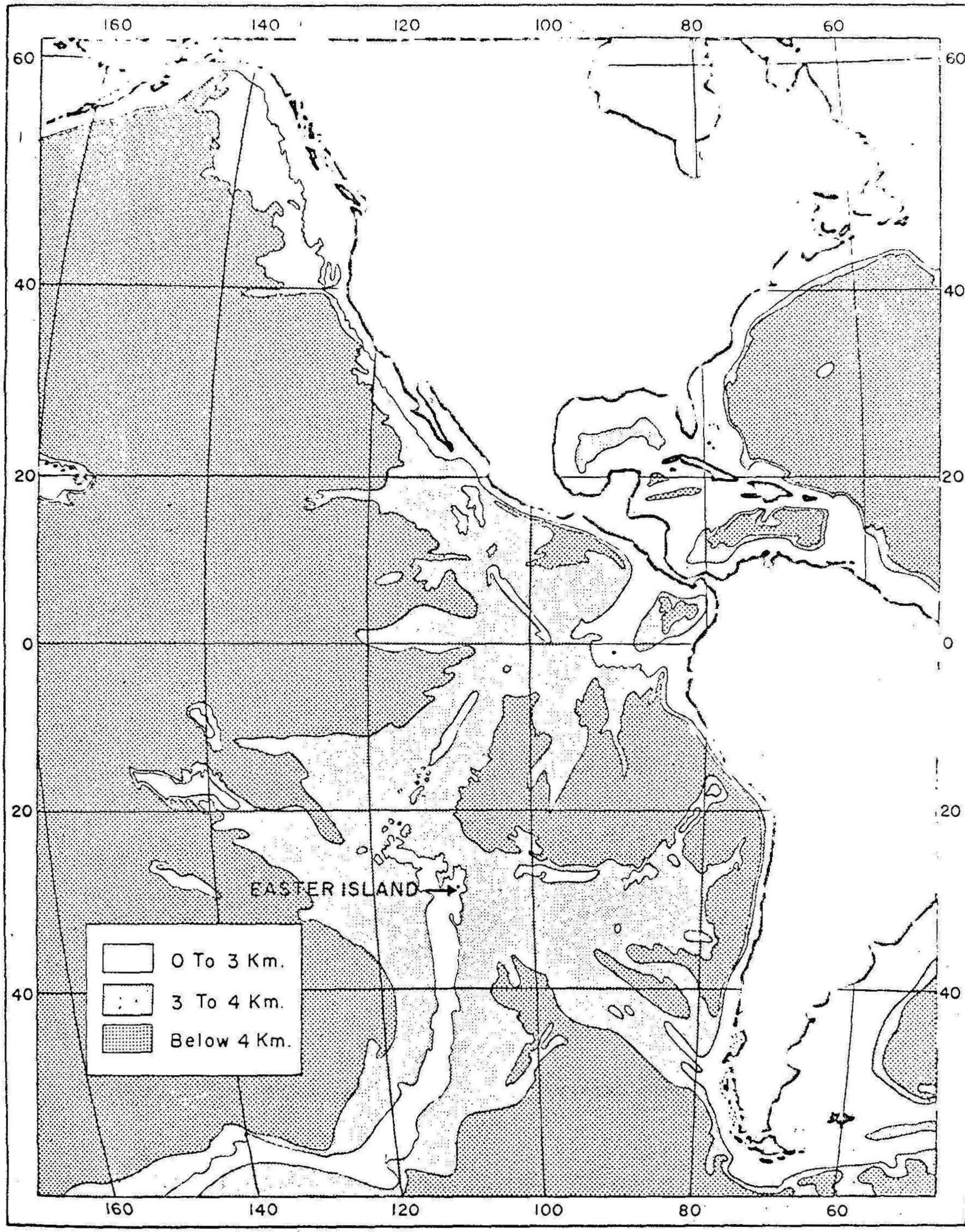
EASTER ISLAND IN RELATION TO THE EAST PACIFIC RISE



after H. W. Menard

C O N T E N T S

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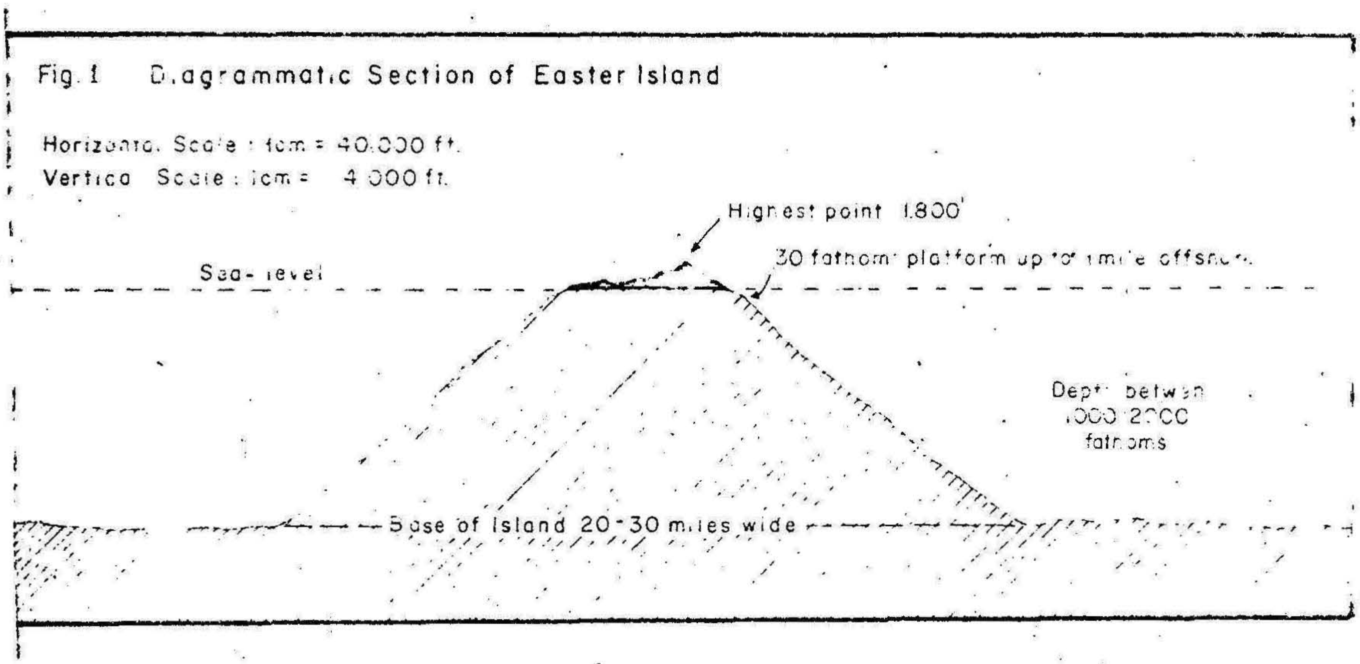


Fig. 1 Diagrammatic Section of Easter Island

A. The Environment

1. Insularity. Easter Island is the triangular summit of an extent volcano rising some 14,000 ft. above

the general level of the floor of the Pacific Ocean, at a distance of 2.000 miles from the nearest point on the coast of South America - which is the Arauco peninsula, Chile. The nearest islands with permanent population are Pitcairn Island, some 1.300 miles to the west; and Mas-a-tierra in the Juan Fernandez Archipielago, some 1.600 miles to the south-east. The centre of Easter Island lies in Latitude 27° 0'S Longitude 109° 26'West.

The nearest regular shipping lines are those using the New Zealand-Panamá-England route which pass close to Pitcairn Island. Easter Island is visited at least once a year by ships of the Chilean Navy but otherwise the island population, numbering about 1200, remains largely isolated. On rare occasions, small open fishing craft from Easter Island have safely made the hazardous voyage of over 2500 miles to Tahiti but several lives have been lost in such ventures.

None of the existing world air routes passes close to the island and the isolation of this small community of Polynesian origin is virtually complete.

2. Land form and geology. Easter Island is composed entirely of volcanic materials which are predominantly of an andesitic type. These include scoria and tuff cones and scoriaceous or/highly vesicular lavas. The triangular shape is due to the presence of three major vents, - one at each apex of the triangle. The broad cones of volcanic detritus around these vents are composed of beds of scoria and tuff interlayered with thin sheets of lava. The southwestern cone, Rano Kao, has a wide, deep crater with a fresh-water lake whose partially reed-covered surface is only a few hundred feet above mean sea-level. The northern volcanic centre (Terevaka) has a smaller crater (Rano Aroi) at an altitude of 1200 ft. which is completely covered by a thick mat offloating reeds. The eastern cone (Maunga Poike) has only a very small dry crater at an altitude of about 750 ft. Another large crater (Rano Rarako) which occurs to the south-west of Poike, contains a fresh-water lake that is nearly covered with a floating reed mat. The centre of the island is lower than the

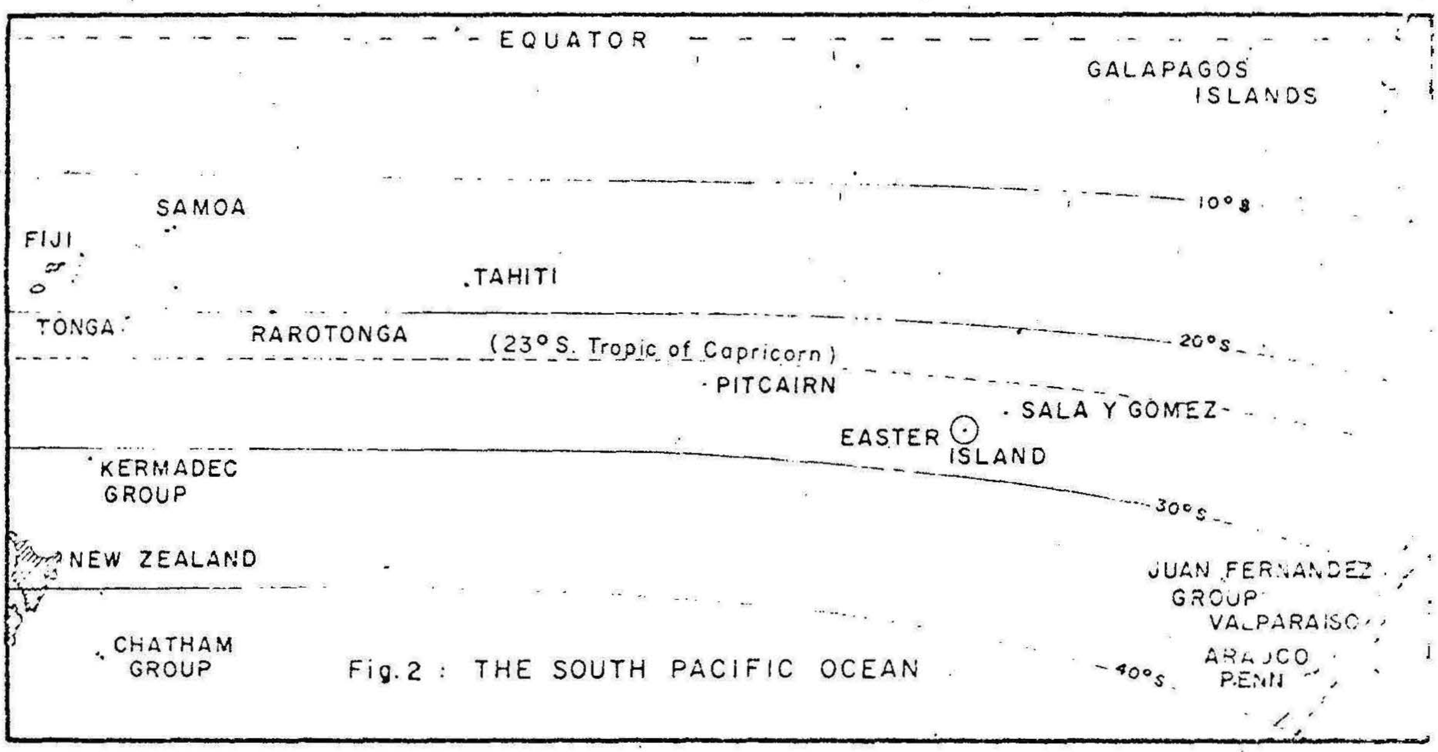


Fig. 2 : THE SOUTH PACIFIC OCEAN

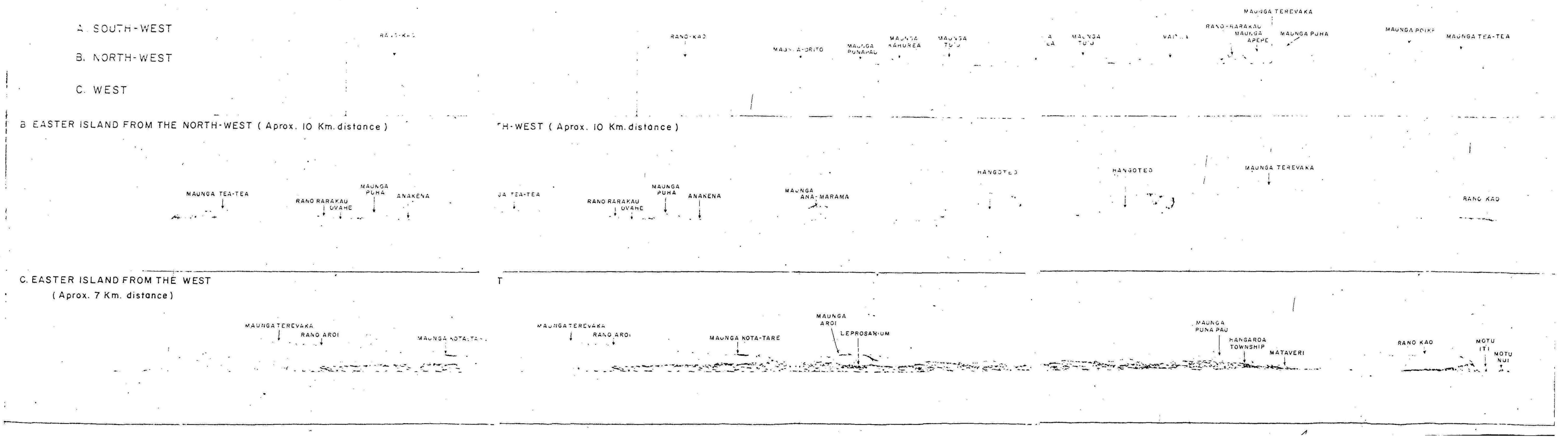
three apices of the triangle. For example the altitude at the approximate geographic centre is only 520 ft above sea level. This central region is formed mainly of lava flows apparently emanating from the northern volcanic centre. Prominent parasitic scoria cones, of characteristic shape and sometimes with small dry craters in their summits, occur in two lines radiating outward from the northern centre of volcanic activity. There is a strong suggestion that Easter Island formerly consisted of 3 separate islands, and that the present islands has been formed by the later infilling of the space between the original islands by lava and scoria. Chubb (1) reports that the lava from Terevaka overlaps the ash and scoria beds of Rano Kao and similar evidence exists at the foot of Maunga Poike.

The softer rocks of the three older cones have been eroded and cliffed by the sea, and now form high, blunt promontories. Whereas, by contrast the coastline of the rest of the island is low but formed of jagged darkgrey lava. Because the lava erodes relatively slowly, there are no major bays or harbours in the coastline, no large beaches, and very few protected anchorages. Small irregularities at the fringe of the lava give rise to small bays, but it is only on the north coast, at Anakena, where a parasitic scoria cone occurs at the coast, that a narrow shelving bay has been formed and a small beach of broken calcareous shell has begun to accumulate. The coastline shelves steeply to a 30 fathom platform, which extends up to a mile offshore, and then plunges abruptly to a depth of 1000-2000 fathoms within 20 to 30 miles of the coast (2). Consequently there is no general development of coral around the coast even though mean sea temperatures of $70^{\circ}F$ are probably warm enough. Some scattered growths of a massive form of coral occur at moderate depth and these corals are harvested to make burnt lime for white-washing the houses.

Not only does Easter Island lack beach accumulations of quartz sand, but there is also a general scarcity of gravel and small boulders required for constructional work. There is only one boulder-filled embayment, at Ana-havea, to the South-west of Maunga Poike. There are no permanent flowing rivers on the island, and consequently no river gravels occur. For major construction works, such as the airstrip and for roads, rock crushing machinery will be essential, and for high-grade cement work quartz sand will have to be brought from the mainland in bulk quantities.

Easter Island is about 45 sq. miles in area. (14 miles along the longest axis and 7 miles at the widest breadth), i.e. about 30,000 acres in extent. The general landform of the island is best appreciated from the sea. Fig. 3 shows the appearance of the island, viewed from the south, the west and the north. Fig. 4 shows the landform viewed from Ranokao looking to the north-east across the island. The prominent small hills are almost invariably formed of andesitic scoria (Fig. 5); the gentle slopes sweeping up to higher elevations are tuff and scoria beds, with thin layers of weathered lava, of the older volcanic centres (Fig. 6); and the lowlands are a lava-filled plain (Fig. 7). The lava flows appear to have been highly gaseous for most of this rock is exceedingly porous and

Fig 3 THE EASTER ISLAND LANDFALL



gas-tunnels are very common. Small fissures in the surface of the lava usually lead into much larger underground chambers, - an aspect of the landscape that was put to good use during the period when warfare and cannabalism was rife on the island. In some places the roof of a subterranean chamber has collapsed producing a sunken pocket in the plain; these areas were formerly valued garden sites for here delicate plants could be guaranteed protection from all but the strongest winds. Where the lava over-ran tuffaceous beds, the latter were hardened along the contact. Where accessible, these flag-stone like slabs were used formerly by the Polynesians for crude house construction, as seen at Orongo, near the lip of Rano Kao crater.

The earliest islanders were adept stonemasons and shaped, fitted and bored some of the hardest rocks. In later periods they concentrated more on the more easily worked andesitic tuff, - particularly that forming the wall of Rano-Rarako crater where probably some 1000 'moais' were quarried. Chisels of harder fine-grained lava were used to chip away at the tuff which is not particularly hard when fresh but which slowly hardens on exposure. The tuff is studded with darker coloured basalt lapillae, giving the rock a warty appearance which mislead one early visitor to consider the monuments as moulded from clay and later studded with fine gravel. As final chore these statues were fitted with a cap stone quarried from red scoria in another part of the island. Moving the statues and cap stones from their respective quarry sites to their appointed ahu' was accomplished along pre-determined routes. A great quantity of small lava fragments was spread over the surface of the ground (to even out irregularities in the micro-relief and to provide a 'rolling' surface) in front of the recumbent statue, and gathered from behind as the statue progressed. A by-product of this labour was an occasional carpet of loose rock left on the plain, often subsequently used for taro plantations because of the better moisture conditions in the soil below the 'stone' mulch.

Another type of rock on the island which owes its displacement to human agency is obsidian. The main outcrop is on Maunga Orito; but obsidian chips, spear heads, axes, etc. occur almost everywhere on the island. When these appear in the soil profiles they help to confirm the degree of soil movement and distrubance that has taken place. Obsidian is the hardest rock on the island and is practically unweathered. The tuff beds and scoria are amongst the softest rocks and, in many places there have weathered to produce clay several feet in depth. Heyerdahl (ibid) reports the discovery of pottery on the island, but the type of clay available on the island would not be well suited for pottery manufacture and it is not surprising that calabash containers were in general use until recent times. The Melanesians of the small andesitic volcanic islands in the Fiji archipielago were often forced to travel to larger islands with sedimentary and quartz-rich rocks seeking clay suitable for pottery manufacture. The clay of pottery unearthed by Heyerdahl on Easter Island might have an interesting story to tell.

To some extent, all the above mentioned rocks (except obsidian) become the parent material of soils. In most cases unweathered rock grades smoothly into the clay weathering products. The thickness of this clay varies greatly. It is thinnest over the most recent lava flows and deepest over the older scoria and tuff beds. In many places, however, the clay does not form the surface soil which has a silty or fine sandy texture. There are reasons, discussed later, why this lighter and looser material cannot be satisfactorily explained as a product of normal genetic soil processes of a soil developed from the underlying rock, and one is forced to consider the possibility of volcanic ash accumulation. In places the light-textured soils reach a depth of over 3 feet.

Careful soil examination along transects radiating outward from the main volcanic centres failed to demonstrate any regular increase or decrease in the light-textured material. The thickest accumulations occured on the western and northern slopes of Rano Kao and Maunga Poike; but were also present, sporadically, on the lava plain. There was also some thickening towards the lip of the high coastal cliffs. The distribution of the pattern of this fine material represents more a general mantle of volcanic dust that has been drifted by the prevailing easterly winds and probably forms some part of the top-soils in all sectors of the island. It certainly does not have the characteristics of an ash shower but resembles more a kind of volcanic loess. Its presence on an island so very isolated appears peculiar until one recalls the 400-500 foot cliffs of Poike and Rano Kao peninsula. These cliffs are eroding rapidly, are largely devoid of plant cover and are exposed to the easterly tradewinds. Islanders confirm that dust clouds are commonly generated over the easten apex of the island, and that dust pillars often arise in the centre of the island over areas of recently burned pasture land. These, plus some redistribution by erosion during heavy rainstorms, might be adequate to account for the distribution pattern of the light-textured material. A similar phenomenon has been reported from Chatham Island, New Zealand (3).

3. Climate The climate of Easter Island of warm and moderately humid type, not, unlike that of Raoul Island in the Kermadec archipielago (4).

Meteorological records extend over only some 15 years but sufficient data has accumulated to establish the general character of the climate. Some of the earliest records available are those of Knoche (5) who maintained a very complete set of weather stations from May 1911-April 1912, - a period which happily proved to be fairly close to average conditions for the island. Knoches' records are the only ones to include data on evaporation rates and soil temperatures at various depths.

Mean air temperatures are of the order of 70°F (Raoul Island, 66°F) with mean morining and evening temperatures falling to 66°F and midday mean temperatures rising to 74°F. The mean minimum air temperature is 62°F (Raoul, 61°F) and the mean maximum air temperature is 75°F

TABLE IA - SUMMARY OF THE METEOROLOGICAL RECORDS FROM MAY 1911 - APRIL 1912. (W. KNOCHE, ET AL).

		1911								1912				
		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	YEAR
AIR TEMPERATURE ºC	7 a.m.	19.0	18.5	17.1	17.0	17.3	17.4	19.4	21.2	22.4	22.8	21.8	19.6	19.5
	2 p.m.	23.1	20.7	20.2	20.3	21.0	20.5	21.9	24.0	25.6	27.1	24.9	22.6	22.7
	9 p.m.	19.2	18.6	17.5	17.2	16.7	16.5	18.1	18.9	21.1	22.1	21.4	19.6	18.9
	Maximun	24.2	22.3	21.4	21.3	21.9	21.7	22.7	25.2	26.9	29.3	26.3	24.3	23.9
	Mínimun	17.0	15.9	14.7	15.2	15.0	14.1	16.1	17.2	19.2	20.4	19.9	18.4	16.9
RELATIVE HUMIDITY %	7 a. m.	79	83	84	84	81	72	78	71	78	79	82	82	79
	2 p.m.	66	74	71	71	66	62	68	62	66	62	70	71	67
	9 p.m.	78	83	82	81	83	78	82	81	83	81	83	82	81
RAINFALL m.m.	7 a.m.	34.3	100.3	51.1	34.7	48.0	71.0	49.9	6,2	22.8	4.6	75.7	97.3	—
	2 p.m.	8.5	54.6	15.1	5.7	4.1	25.7	22.1	7.1	6.1	5.8	81,7	49.4	
	9 p.m.	14.2	91.5	19.5	10.3	46.6	24.1	3.1	6.3	30.5	9.1	124.8	28.7	
	7 a.m.to 7 a.m.	57.0	240.5	91.6	47.9	81.4	120.9	75.1	14.7	64.3	19.5	269.5	186.3	1268.7
EVAPORATION m.m.	7 a.m.	21.0	21.7	22.8	19.8	16.8	22.8	17.8	17.9	16.9	18.1	17.8	18.4	
	2 p.m.	34.4	25.2	27.1	32.9	30.9	34.5	30.4	39.2	37.3	46.6	33.1	28.0	
	9 p.m.	30.7	21.8	30.2	29.1	25.6	27.8	26.5	29.6	31.7	37.2	29.1	26.3	
	7 a.m.to 7 a.m.	86.8	69.7	78.9	82.0	73.3	84.6	74.8	86.9	83.4	100.7	83.9	72.4	977.4

TABLE IB - SUMMARY OF THE METEOROLOGICAL RECORDS FROM MAY 1911 - APRIL 1912. (W. KNOCHE, ET AL).

			1911								1912					
			May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	YEAR	Mean Soil temp. "
CLOUD COVER (tenths)		6 a.m.	5.5	6.5	6.8	7.8	6.9	6.3	6.9	5.6	4.9	4.6	6.3	6.9		
		7 a.m.	6.0	7.4	7.3	7.5	7.2	6.5	7.2	7.7	5.4	4.9	6.9	7.5	6.6	
		10 a.m.	6.5	7.9	7.3	7.4	7.0	7.1	7.8	6.9	6.6	5.8	7.3	7.3		
		Midday	6.5	7.8	7.4	7.7	7.2	7.1	7.7	6.3	6.7	5.9	7.8	7.4		
		2 p.m.	6.5	8.1	6.8	7.2	6.5	7.0	7.6	7.5	6.5	5.8	7.5	7.4	6.9	
		4 p.m.	6.1	8.5	6.5	7.4	7.0	7.5	7.6	6.3	6.7	6.1	7.9	7.2		
		6 p.m.	5.5	7.0	5.8	7.4	6.5	7.1	7.6	5.8	6.1	5.9	7.3	6.6		
		9 p.m.	4.4	6.4	5.6	6.5	6.2	5.9	5.0	4.2	3.2	2.8	5.4	6.1	5.0	
SOIL TEMPERATURE ºC	0 cm	7 a.m.	16.5	16.2	15.5	15.6	15.4	15.8	20.6	24.1	22.8	22.8	20.7	18.7	18.7	
		2 p.m.	30.2	24.5	25.0	29.1	30.6	33.2	31.7	42.9	39.8	51.2	37.3	39.2	34.0	22.3
		9 p.m.	16.9	16.8	15.3	15.8	15.3	15.8	17.3	18.4	20.7	25.3	21.5	19.4	18.2	
	5 cm	7 a.m.	18.3	17.9	17.5	17.3	18.0	18.0	19.3	21.0	21.9	23.4	21.4	18.8	19.4	
		2 p.m.	24.6	21.3	21.1	22.9	24.9	25.1	28.0	34.4	32.3	41.8	31.2	28.9	28.0	23.0
		9 p.m.	20.0	18.8	18.3	19.1	20.6	20.8	21.2	22.9	24.4	27.6	23.7	20.2	21.5	
	10 cm	7 a.m.	20.5	19.1	18.5	18.8	19.7	20.2	21.5	23.8	24.7	27.2	23.6	20.3	21.5	
		2 p.m.	20.0	19.8	18.4	19.8	21.2	22.2	24.2	27.6	27.9	31.9	26.1	24.4	23.8	23.0
		9 p.m.	21.9	19.9	19.4	20.1	21.5	22.0	23.7	27.1	28.4	31.6	26.2	22.4	23.7	
	Maximum at 9 p.m.		37.2	30.5	31.4	34.1	37.8	39.0	41.6	47.5	46.3	49.3	38.8	35.7		
	Minimum at 9 p.m.		14.2	13.8	12.7	12.9	12.4	11.6	14.6	14.8	17.0	17.2	16.1	14.8		
HOUR OF SUNSHINE	Total for month		196.9	134.9	179.4	157.6	194.3	219.1	193.7	273.2	231.5	273.1	175.1	184.6	2443.4	
		%	59	43	55	46	54	56	38	64	62	72	46	54		

TABLE 2A - MEAN MONTHLY METEOROLOGICAL DATA FOR EASTER ISLAND

MATAVERI STATION (LAT. 27º10'5, LONG 109º26'W), 125 FT. ABOVE SEA-LEVEL

	Jan.	Feb.	Mar.	Apr.	May	June	July	Ag.	Sept.	Oct.	Nov.	Dec.	Year
Mean Temperature ºC	23.1	23.7	23.1	21.5	19.9	18.3	17.8	17.8	18.1	19.1	20.2	21.8	20.4
Mean max. temp. ºC	27.0	28.2	27.4	25.5	23.4	21.9	21.4	21.5	22.1	23.3	24.2	25.5	24.3
Mean min. temp. ºC	19.1	19.6	19.3	17.8	10.9	15.1	14.6	14.7	14.5	15.2	16.3	17.9	16.8
Absolute max.temp.ºC	31.0	31.0	30.8	30.0	28.0	26.2	27.0	25.3	26.0	27.5	28.0	29.3	31.0
Absolute min.temp.ºC	12.0	14.0	15.0	12.7	11.0	9.3	9.5	8.0	8.0	10.0	10.0	12.0	8.0
Rel. Humidity Aire %	81	79	80	80	83	83	84	83	81	80	82	82	82
Cloudines (0 - 8)	4.5	4.2	4.6	4.9	5.4	5.4	5.4	5.5	5.4	5.4	4.7	4.8	5.0
Wind dir. & force (mean)	E 3	E 3	E 2	E 3	E 3	Var 2	NW 3	NE 2	NW 3	E 2	E 3	E 2	E 2
Wind.dir. & force (max.)	E 6	E 6	Var 5	E 7	E 9	N/NW 7	NW 7	W 8	N 7	SE 7	N/NW 7	Var 6	E 9
Rainfall total (mm)	101.1	83.2	112.6	113.8	117.6	128.5	92.0	89.9	76.2	69.7	111.4	126.9	1,232.9
Rainfall 24 hr.max.(mm)	160.0	47.3	75.0	59.9	98.0	167.7	60.2	75.7	75.4	48.0	90.9	81.0	167.7
Rainfall 24 hr.max (year)	1919	1939	1912	1912	1942	1913	1939	1919	1918	1941	1913	1943	1913

TABLE 2B - MEAN MONTHLY METEOROLOGICAR DATA FOR EASTER ISLAND

MATAVERI STATION (LAT. 27º10'S, LONG 109º26'W), 125 FT. ABOVE SEA-LEVEL

Days with rain (1912/14)	12.9	11.3	14.2	14.1	14.7	13.6	14.3	12.7	14.1	10.2	10.7	11.1	153.9
Days with drizzle (1937/46	-	0.1	0.1	0.5	0.3	0.6	0.3	0.4	0.6	0.7	0.6	0.3	4.5
Days with fog	0.1	-	0.1	0.1	0.4	-	-	0.1	-	-	-	-	0.8
Days with clear	1.8	1.5	1.8	1.3	0.5	0.4	1.0	0.5	0.7	0.4	0.8	1.8	12.5
Days with overcast	6.5	4.2	5.6	8.6	11.6	9.8	10.8	12.6	18.8	10.3	10.2	11.3	113.3
Days frost	-	-	-	-	-	-	-	-	-	-	-	-	-
Days hail	-	-	-	-	-	-	-	-	-	-	-	-	-
Days snow	-	-	-	-	-	-	-	-	-	-	-	-	-
Days thunderstorm	0.1	0.5	0.2	0.2	0.2	0.1	0.1	-	0.1	-	0.1	-	1.6

Pressure in millibars	1015.0	1014.6	1014.1	1013.8	1013.7	1015.0	1016.4	1017.7	1017.0	1018.2	1014.6	1014.6	1015.4

TABLE 3A - MEAN SEASONAL METEOROLOGICAL DATA FOR EASTER ISLAND MATAVERI STATION (LAT. 27º10'S, LONG 109º26' W) 125 FT.ABOVE SEALEVEL

		Nº of Years	Summer	Autumn	Winter	Spring	Year
TEMPERATURE (ºC)	Mean	9	22.3	21.5	18.6	19.1	20.4
	Mean maximun	9	26.9	25.4	21.6	23.2	24.3
	Mean mínimun	9	18.9	18.0	14.8	15.3	16.8
	Absolute maximun	9	31.9	30.8	27.0	28.0	31.0
	Absolute minimun	9	12.9	11.0	8.0	8.0	8.0
	Relativa Humidity Air %	9	81	81	83	81	82
RAINFALL (mm)	Total rainfall	17	321.2	344.0	310.4	157.3	1,232.9
	Maximun in 24 hrs.	12	160.0	98.0	167.7	90.9	167.7
	Year when 24 hrs. max. occ.		1919	1942	1913	1913	1913
	Claudiness (0 - 8)	12	4.5	5.0	5.4	5.2	5.0

TABLE 3B - MEAN SEASONAL METEOROLOGICAL DATA FOR EASTER ISLAND MATAVERI STATION

(LAT. 27º10'5, LONG 109º26' W) 125 FT.ABOVE SEALEVEL

Nº of days with-		Yrs.	Su.	Au.	Wi.	Sp.	Yr.
	Rain	11	35.3	43.0	40.6	35.0	153.9
	Drizzle	9	0,4	0.9	1.3	1.9	8.5
	Fog	11	0.1	0.6	0.1	---	0.8
	Clear	11	5,1	3.6	1.9	1.9	12.5
	Overcast	11	22.0	25.8	33.2	32.3	113.3
	Frost	11	---	---	---	---	---
	Hail	11	---	---	---	---	---
	Winds over Force 8 (Bft)	11	0.1	0.4	0.3	---	0.8
	Thunderstorm	11	0.6	0.6	0.2	0.2	1.6

Atmospheric Pressure (mbs)	9	1014.7	1013.4	1016.4	1016.6	1015.3

	N		NE		E		SE		S		SW		W		NW		CALM	
	Force	%	Force	%	Force	%	Force	%	Force	%	Force	%	Force	%	Force	%	Force	%
Summer	2	7	2	19	2	43	2	6	1	1	1	3	2	4	2	13	---	4
Autumn	2	10	2	10	2	36	2	6	2	5	2	5	2	8	2	13	---	7
Winter	2	13	2	11	2	16	3	8	2	6	2	10	3	14	3	18	---	4
Spring	3	12	2	12	2	29	3	9	2	5	2	5	2	8	2	18	---	2

(Raoul, 71°F). The warmer month is February and July the coldest, but the difference is only of the order of 10°F. Knoche (ibid) postulates a decrease of about 1°F for every 300 ft of altitude. At altitudes of over 1000', the air is notoriously cooler, even at midday.

The mean rainfall is of the order of 49 inches per annum (Raoul, 59") and is subject to marked deviations form the norm. In some years, rainfall rises to over 70" and, in a few severe drought years, has fallen as low as 28". The number of days with some rain, in an average year, is 154 but rainfall is inclined to be very local, falling as brief, intense showers covering only a comparatively limited area of the islands. The onset of rainfall is also inclined to be erratic, more common with a falling barometric pressure but not associated with any particular shift in wind direction. Occasionally rainy weather for a duration of 8-16 hours is known but this is not common. The highest daily rainfall ever recorded (June 1913) was 6'5 inches. There is no clear seasonal rhythm to the rainfall, - no regular rainy season or dry season. The mean monthly average shows a small steady increase from March to June (5.1") and then a gradual decrease to a low in October (2.8"), very similar to the subdued rhythm experienced in Raoul Island (maximum in July 6.5"; minimum in November, 2.9"), (Table I).

The main recording station is at Mataveri, at an altitude of about 125 ft. above sealevel. Knoche (ibid) operated 2 subsidiary rainfall stations for a year at 960 ft and 540 ft respectively, and found that the higher station collected nearly 40 inches more rainfall than the main station during the year. The islanders concur that the higher parts of the island, and also the central lowland of the island receive more rain than Mataveri, and also point out that the eastern promontory, Poike, is considered to be the driest part of the island. The sketch map showing probable mean annual rainfall Fig. 8, incorporates these features.

The mean relative humidity of the air is high, amounting to 82% for the year (Raoul, 76%). The air is slightly less humid in March (79%) and most humid in July (84%). During all months except June, July and August, the relative humidity of the air falls below 70% at midday, and normally exceeds 80% throughout the night. Commonly there is heavy condensation of dew in the early morning.

Mean cloud cover for the year is 5/8, with the period May to October having slightly more cloud than the rest of the year. An average of 13 days in the year are completely without cloud, but even on cloudy days the clouds are usually moving rapidly, and the total amount of direct sunshine is high, amounting to over 2000 hours per annum (i.e., over 50% of the day-light hours are sunny). Fog and drizzle are almost unknown. Frost, hail and snow have never been recorded. Even thunderstorms are rare.

The wind blows more or less steadily from the east but with only a very moderate velocity (mean value for year, E.2). From June to September, the winds tend to become variable, moving through and are from north-east to north-west. Very strong winds are uncommon and of short duration, but it is a distinct feature of the island climate that the air is always in motion. Calm days average less than 3%. Wind velocities are considerably greater on the hills. Knoches' high level station recorded velocities averaging 2 to 3 times those experienced at the main station and, often were more than doubled. The wind velocity normally reaches its maximum near midday, falling for a while at dusk, rising slightly at night and falling again near dawn.

A characteristic of the island climate is the very sharp difference in air temperatures between sun and shade readings. This is also reflected in the soil temperatures to a striking degree. In general the exposed soil is slightly warmer than the air in February and slightly cooler in July. The average topsoil temperatures in the open range between 4°F and 6°F warmer than the air, and the soils at a depth of 4" maintain some 6°F warmer than the air throughout the year. Beneath heavy shade in tree plantations, soil temperatures to a depth of 4", usually keep below 60°F; whereas in the open, under a sparse cover of Sporobolus pasture, temperature of over 120°F were recorded by one of the authors in January (1962) for the top inch of soil, and temperature of over 95°F were common to a depth of 4 inches. During the night, soil temperatures at a depth of 2 inches, under pasture, dropped to 75-80°F; whereas those in the forested soil at equivalent depth scarcely showed any change from their daytime reading. In 1911-12, Knoche reported mean annual midday soil surface temperatures of 95°F, falling to 82.5°F at 2 inches depth and 77°F at 4 inches below the surface. The maximum mean monthly surface soil temperature recorded by Knoche was 120°F for February 1912.

The combination of almost contenuous air movement, rapidly changing cloud patterns, high insolation; brief and intermittent showery rainfall, high soil temperatures and virtual absence of forest cover to check air movement and shade the soil, all operate in favour of high evaporation rates. The only mitigating factor is the he vy dew condensation in the pre-dawn hours, but by 10 am. this moistures has usually evaporated. The only measurements of evaporation rates ever carried out on Easter Island are those of Knoche (ibid) who showed that, for the period May 1911 - April 1912, evaporation amounted to 3/4 of the actual precipitation. During 5 months of the year evaporation exceeded precipitation. If these figures of evaporation rates can be taken as any guide to the effective moisture regime of the island, the net gain to the water reserves of the island may be as low as 10-15 inches per year.

Skottsberg (6) draws attention to the anomaly that in the Juan Fernandez archipielago, Más-a-tierra Island has a lower rainfall than Easter Island, but has abundant surface water, springs and once had a luxurious forest vegetation. The waterless landscape of Easter Island has often been blamed on the porous nature of the volcanic rock, but it is more likely that Easter Island, with its low, treeless landscape, persistant trade wind, and high insolation, loses a large

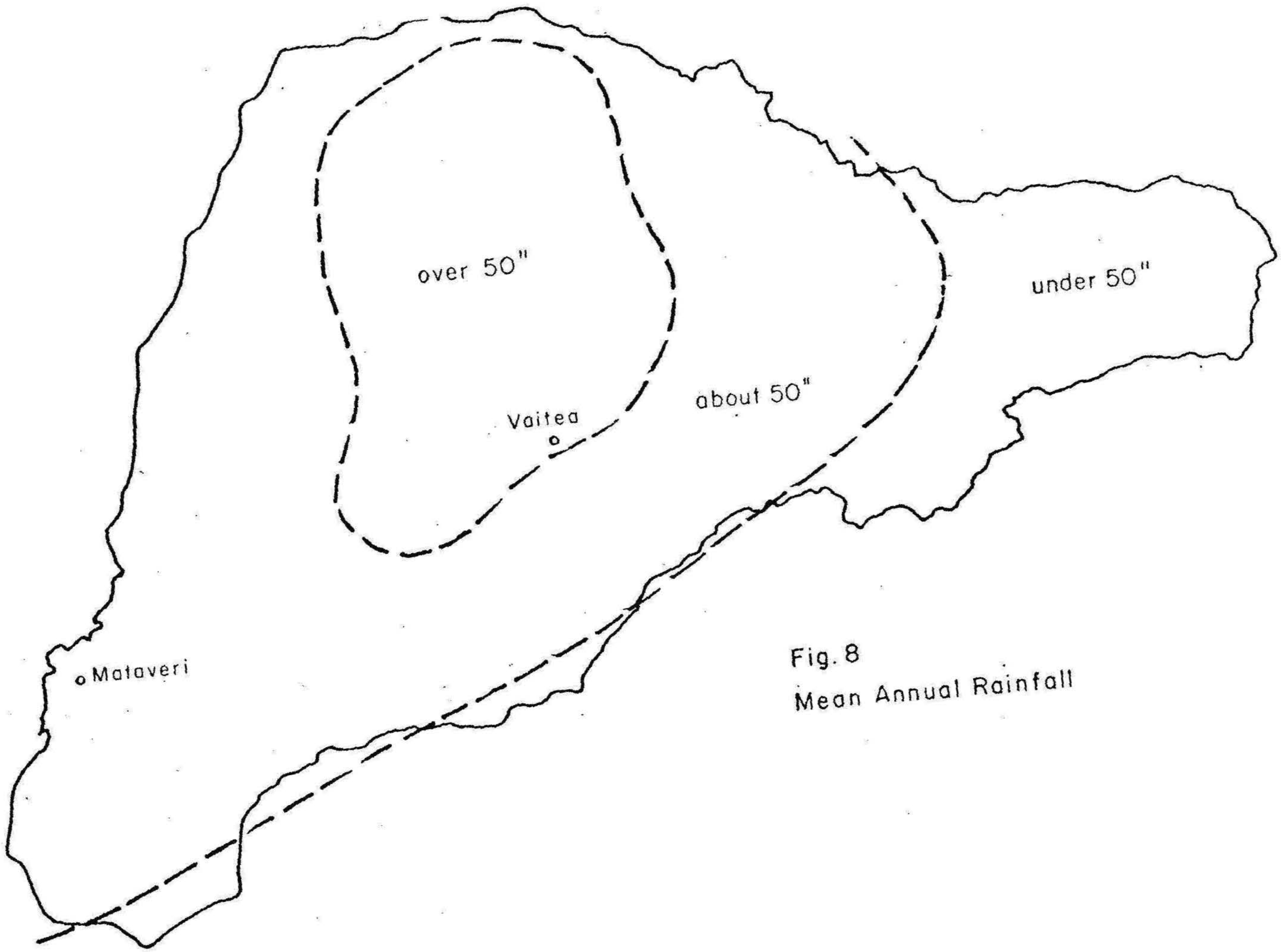


Fig. 8
Mean Annual Rainfall

part of the rain fall through intense evaporation during the middle of the day. To safe-guard their essential food crops, the ancient inhabitants of the island sought sunken areas with natural shelter or built stone walls to create shelter from the wind. This, and the use of rock strewn ground, probably were two measures aimed at securing the maximum use of the existing soil moisture, rather than to counter to the physical action of the wind on plant foliage.

Heyerdahl (ibid) sums up the island climate as a fairly equable, semi-tropical climate; Skottsberg (ibid) as a 'oceanic warm temperature climate dominated by trade winds'; and Knoche (ibid) as 'tropical', with close similarity to that of Puerto Orotava, in Teneriffe. I would appear to be true to say that the temperature is equable and warm to very warm; but the moisture regime is erratic, with an unusual combination of a humid oceanic air stream and hot, dry soil conditions. Even the approach of the fringe of the Humbold current from September to March does little to disturb the regular rhythm of the island environment.

4. Plant cover The original, natural, plant cover of Easter Island has been the subject of some speculation. The earliest European visitors were unanimous in their comments on the presence of food gardens set in a treeless landscape, with reference to 'woodland (7), shrubs and brushwood' (8) seen in the distance. Forster (9) reported that he saw no tree over 10 ft high on the island, and commented on the presence of a low forest of crooked "toromiro" (Sophora) trees 6-7 ft high. La Perouse (10) was the first, in

print, to speculate upon the possibility that the island had once been densely wooded, and once rich in springs and brooks.

Skottsberg(ibid, p 492 etc.) was the first to advance an explanation for the treeless landscape in an environment quite well suited to tree growth. He considers that it is due to the extreme isolation of Easter Island and the failure of tree seeds to survive the long sea journey. The only tree fruit or seed to make the crossing safely appears to have been that of Sophora toromiro. The only other shrubby woody plant was Lycium carolinian; for the rest the original vegetation was predominantly herbaceous. Skottsberg suggests that the original plant cover was a park-like savanna with groves of trees and shrubs in sheltered depressions and on the lee slopes of the hills, and grossland on all the more exposed hillsides and exposed plains, - an arrangement not unlike that still to be found on the drier highlands of some of the Hawaiian Islands, and the windswept uplands of the Juan Fernandez Islands.

Owing to the erratic moisture regime of the environment, vegetation on Easter Island is exceedingly susceptible to modifications by burning. This factor, and the inroads of agriculture, probably brought about the barren appearance of the landscape that called forth comment from the early navigators. During the first half of the present century a single toromiro tree was still reputed to be growing on the inner wall of Rano Kao crater. This may now have died.

A surprising number of plant introductions appear to have been made before the Europeans came into the Pacific. There is some evidence that the coconut palm had been introduced and died out prior to the collecting expedition of Arup in 1868 (11). Yams, sweet potatoes, taro, gourds, bananas, sugar cane, te (Cordyline), tumeric, sandalwood, and various trees and shrubs with a fibrous bark and other diverse uses, (Triumfeta semitrilobata; Sapindus saponaria, Hibiscus tiliaceous, Thespia populinea, Broussonetia papyrifera) were all established on the island prior to the arrival of the first missionaries (12) (13) (14). Yams growing wild still occur on the lower slopes of Rano Kao crater and taro plants survive in various rock parts of the lowland lava plain, even though these plants are no longer widely cultivated for good. Gourds, which were plentiful in 1911, appear to have died out.

The original grassland vegetation has suffered changes no less than the original forest and shrub communities. It was Forster (ibid) who first recognised a grass that covered the land on either side of the partially cleared paths to the food gardens as a thin, perennial, Jamaica grass. Subsequently this became Paspalum Forsterianum. Skottsberg (ibid, p. 63 etc.) also records as evidence grasses Sporobolus indicus, Paspalum scrobicularium, Axonopus paschalis, Stipa horridula, Danthonia paschalis, and some seven or eight other grasses that may have been accidentally introduced during the past century. Many of these grasses collected by Fuentes (ibid) and Skottsberg (ibid) have become exceedingly rare and the island has now become over-run by one single native species - Sporobolus indieus. Heavy grazing pressure by sheep, which first appeared on the island in 1871 and were very heavily stocked on the island between 1915 and 1936, and repeated burning of dry grass to induce new, tender shoots to keep the sheep alive, are the chief factors that have wrought profound changes in the original grassland community.

The only other native plant community worthy of note are the reed swamps of the lake-filled craters. This community is dominated by Scirpus riparius, associated with Juncus plebeius, Kyllinga breveifolia, Polygonum acuminatum, and Campylopus sp. and forms a thick mat of vegetation that floats like a raft on the surface of the lake. The mass of live roots, rhizomes and decaying vegetable material is from 4 to 6 feet in thickness; below this raft, discoloured, dark brown water extends to the bottom of the crater.

5. Hydrology: Easter Island is a dry island in the sense that there are no permanent flowing streams and the available natural fresh-water reserves are represented only by the three weed-overgrown crater lakes and a few small springs along the coastline; - and even the latter do not yield truly fresh water except for a brief interval at low tide.

The population collect what they can of the rain which falls on the house roofs, and conduct this by a complex system of pipes and channels to domestic tanks. During the more prolonged intervals without rain the population have to resort to the laborious method of hauling water from the nearest crater, involving 2 climbs of about 1200 ft. Only Vaitea, the old sheep-station homestead, is served by piped water; this is brought about 3 Km from the small crater Rano Aroi.

From the location of former settlements, it is apparent that the main source of domestic water for the islanders was formerly the springs emerging at sea-level at various points around the coast. Some of these springs had been excavated and provided with masonry walls, but undoubtedly potable water would have been available only during the interval of low tide. There are nine main sea-level springs and eight of these have now been cemented over and provided with wind-mill pumps. This water is conveyed to tanks for the use of livestock. A survey of the quality of water on Easter Island was carried out in 1960 by Molina (15) and this water, which has a decidedly salty taste, has a pH ranging from 6.8 to 7.1, 48 to 138 degrees of hardness; between 2000 and 5000 milligrams per litre of chlorides; and between 1000 and 2000 milligram per litre of lime, magnesia and potash salts.

By contrast the water from Rano Aroi and Rano Raraku crater lakes and which is rather insiped to the taste, has a ph of 7.0; less than 15 degrees of hardness; contains less than 500 milligrams per litre of chlorides; and about 2000 milligrams per litre of various dissolved salts. In the crater, the water is strongly discoloured by organic residues from the decaying vegetation mat. In 1961, a siphon was installed in Rano Rarako lake and the water piped to a new storage tank for reticulation to livestock.

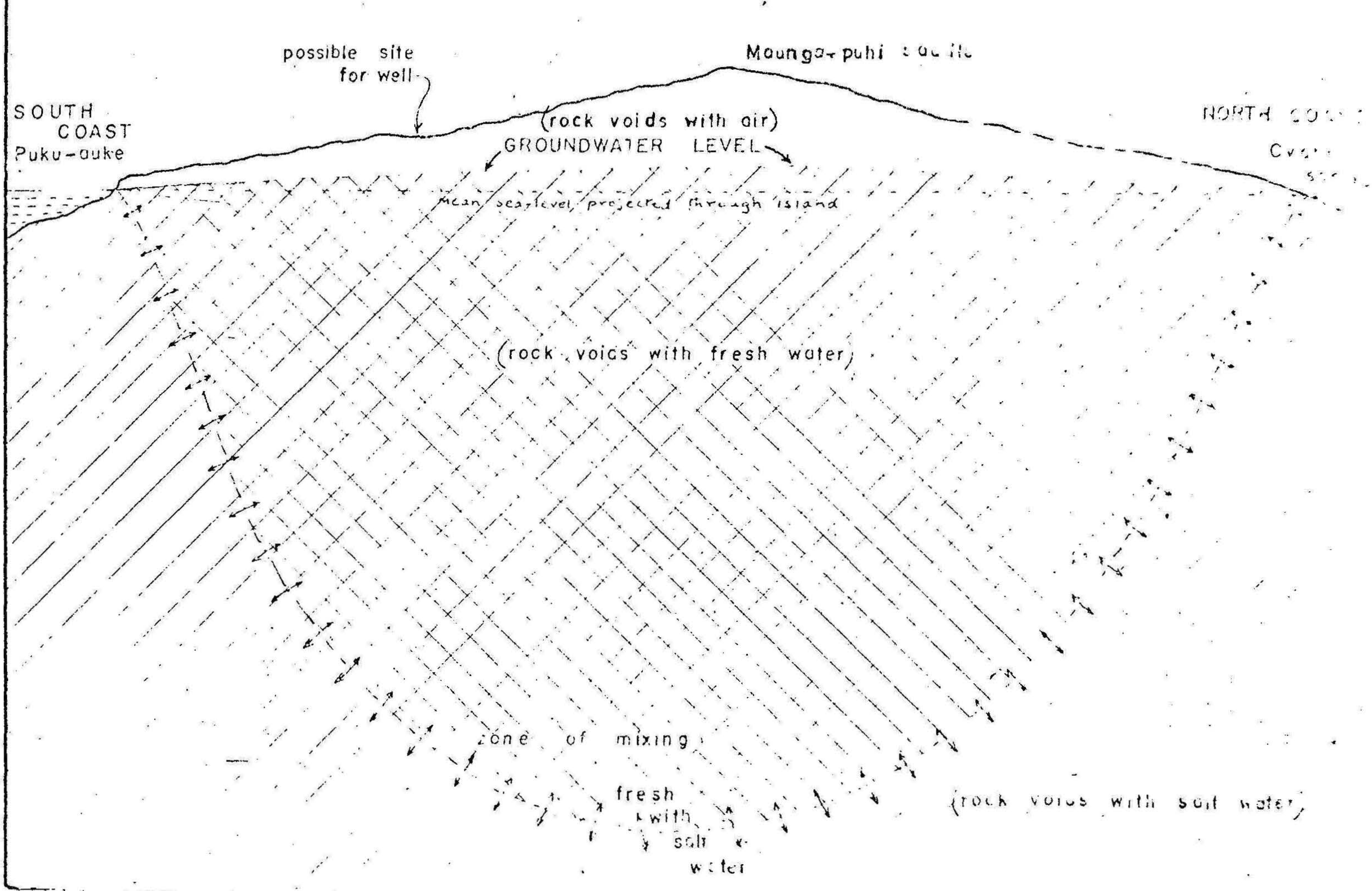
There is one small coastal spring at Mataveri which is probably fed by subterranean leakage from the lake in Rano Kao crater. This spring yields only a very small flow during very dry seasons but has water of good quality (pH 7.0; 23 degree hardness; 760 milligrams per litre chlorides; 1800 milligram per litre of dissolved salts) and is exploited as far as possible for both domestic use and for the animals of the pig farm nearby.

The water in Rano Kao crater itself could be pumped to an intermediate tank and then conveyed by a tunnel and pipeline to Mataveri, and would probably suffice for the needs of the present population if no other source of water can be developed. It is estimated (Molina, ibid, p12) that the potable water requirements of the 1200 persons on the island would be of the order of 2000 litres per person per day, - or a source with a delivery of 2.8 litre per second.

There is little doubt that a large reservoir of fresh water exists below the island. Easter Island is scarcely different from the volcanic islands of Hawaii and Samoa (Stearns, 16, 17; Kear and Wood, 18) and is probably very much better situated in respect of groundwater than the coral island of Niue (Schofield, 19). In all these islands, there is a groundwater gradient from a high point below the centre of the island down the sealevel. These gradients are low

FIG. 12 DIAGRAM SHOWING PROBABLE SHAPE OF FRESHWATER RESER[illegible] ISLAND

Transect south to north from Puku-auke to Ovahe



where the islands are composed of porous rocks (of the order of 1 to 5 feet per mile) but each island has a large lens-shaped reservoir of fresh water in the pores and fissures (voids) of the rocks. This accumulated rain water displaces the seawater that would otherwise fill these voids in all situations below mean sealevel. The theoretical situation in respect of the fresh water reserves below Easter Island is shown in Fig. 10. In this diagram, it can be seen that the thickness of the zone with fresh water in the voids thins out rapidly near the coastline. The aforementioned springs at sea-level are but the leakage from the periphery of the reservoir. Beneath the centre of the island there is probably a depth of several thousand feet of porous rock filled with accumulated fresh water. The best permanent source of sweet water on the island is to be found in this reservoir.

The sweet water reserve can be tapped by excavating or boring wells as far inland from the coast as is commensurate with the depth which has to be penetrated to reach the fresh water. Half-a-mile inland from the coast water may perhaps be found at 50-70 ft, but if the well is to be pumped at a rate of 2 litres per second continuously, there is some danger of infiltration by salt water. It would be better to move as far inland as possible and select a site where the land is relatively low in respect of sealevel, to dig a deep well. The extra work involved is worth the effort if one can have an assured fresh water supply at all times, irrespective of the rate of pumping. Such localities exist near Vaitea; to the north of Maunga Hariha, near Moeiroa, and in several other places. Here ample fresh water supplies are likely to be encountered at a depth of 200 ft or less. At the bottom of the well, short horizontal collecting tunnels should be made in a radial pattern, since these will increase the rate of refilling with fresh water when pumping commences. The approximate sites for exploratory well digging are shown in Fig. 11. Thick lava flows are uncommon in the structure of the island and probably the wells can be dug entirely by hand. The wall of the well should be timbered (and later cemented) to prevent the ingress of loose scoria.

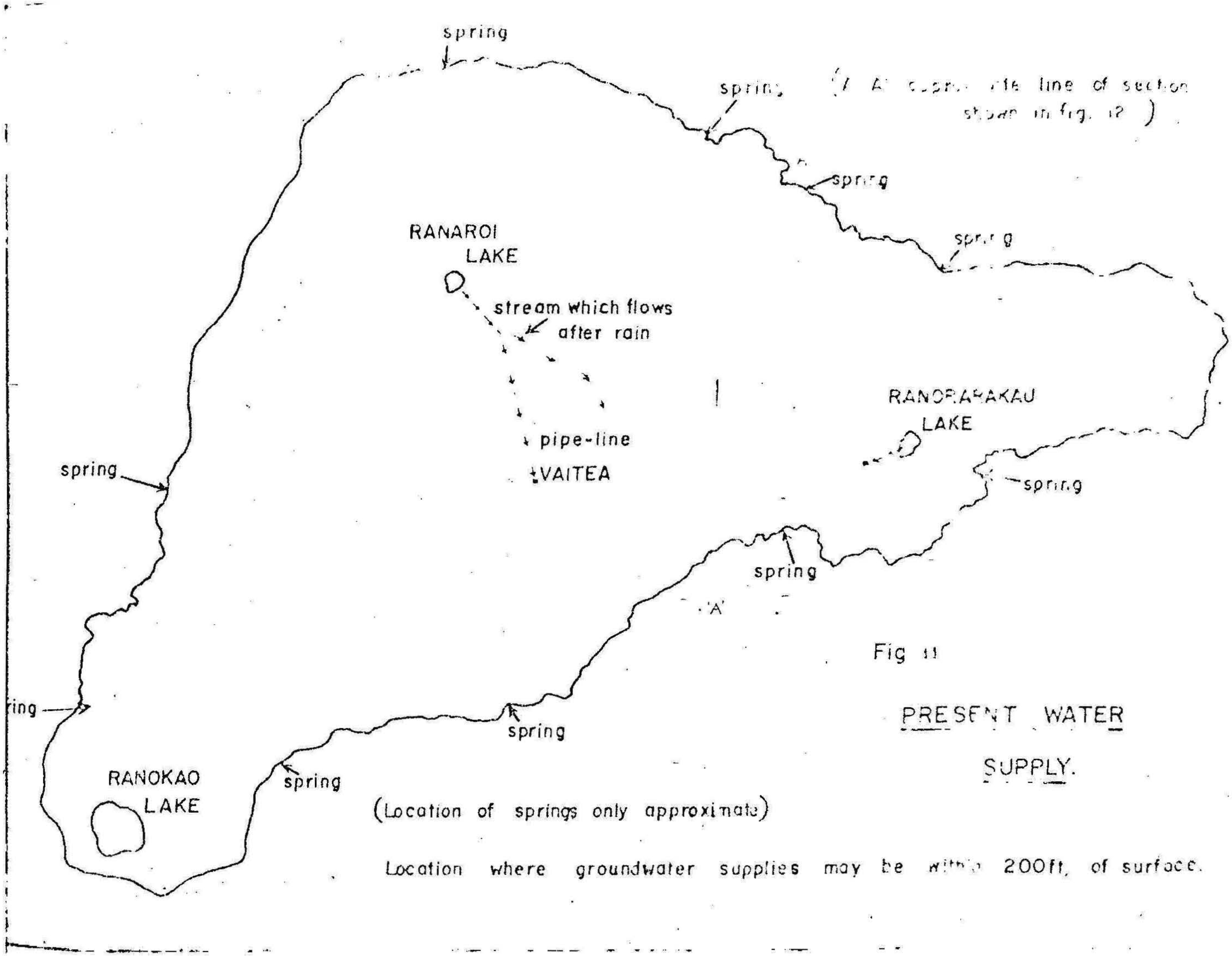


Fig 11

PRESENT WATER SUPPLY.

(Location of springs only approximate)

Location where groundwater supplies may be within 200ft. of surface.

B. The Soils

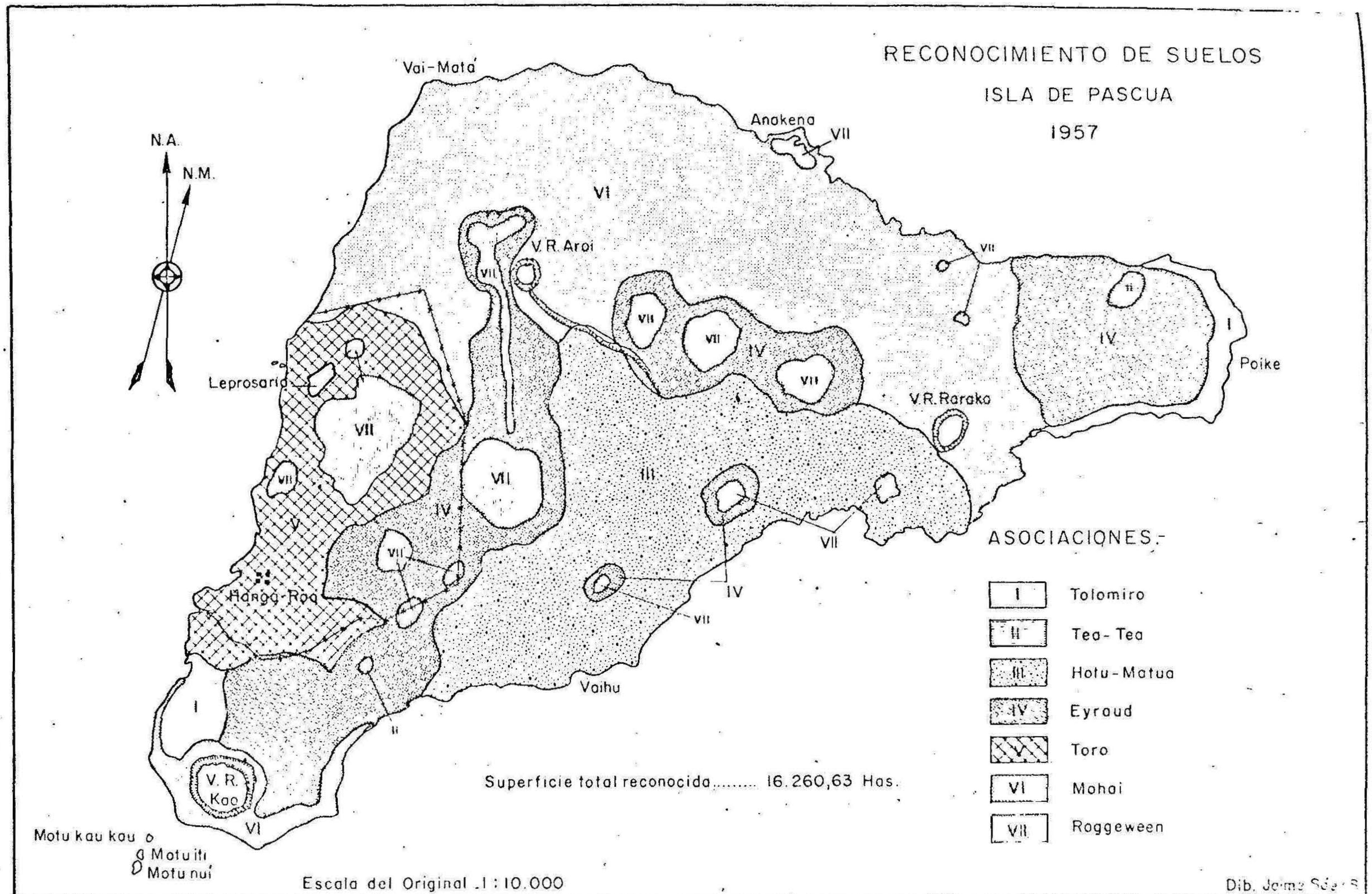
1. The Broad Soil Pattern: The soils of Easter Island have been broadly mapped by Carlos Díaz V. (20) in seven associations, in which are grouped 25 soil types.

The greater part of the island is built up of soil derived mainly from andesitic flow rocks and volcanic ash. These fall into 3 main associations, Hotu Matua, Mohai and Toro. Although "volcanic ash" occurs indiscriminately throughout soils of these three associations, there are basic differences between the three associations which appear to be correlated with differences in the relative ages of the lavas. Areas where the "volcanic ash" lies more deeply are separated as the Toromiro series. Soils derived mainly from scoria and volcanic tuff beds are placed in the Eyraud and Roggeween series, the latter being developed mainly on the smaller and younger parasitic cones. Four small cones with very pale coloured volcanic tuff have distinctive soils which belong to the Tea-tea association.

Within the Hotu matua association;. Vaitea soils are deeper and have fewer lava outcrops than Piro-piro soils which are very shallow and rocky; occupying a strip along the centre of the south coast. Vaitea soils have a more inland location and are probably subject to slightly higher rainfall and a more rapid rate of soil movement. Both soils are developed on a sloping plain of undulating to rolling relief, but the general slope of the plain steadily increases from 5-10% in the case of Piro-piro soils, to over 15% for Vaitea soils. This sloping plain has a 'stepped', or rumpled appearance due to successive phases of surface cooling and subsequent re-flowing of lava. The soils of the Hotu Matua Association are dark brown in colour and commonly of a heavy silt loam or silty clay loam topsoil texture, grading to strong (yellowish) brown clay loam or silty clay immediately in the vecinity of the weathering porous lava (see appendix Profile No.1).

In the Toromiro association, two distinct soils were recognised: Rano Kao soils on the northern flank of Rano Kao crater and Raki-raki soils at the extreme eastern tip of Poike promontory. Both soils occur on 20-30% slopes but the Rano Kao soils occupy a fairly sheltered northern slope and the Raki-raki soils occur in an extremely exposed position along the top of high cliffs confronting the trade winds. Both soils appear to contain an admixture of "volcanic ash", both are strongly eroded, and both have a characteristic orange-red colour. Raki-raki soils are silt loams or fine sandy loams resting on silty clay whereas Rano Kao soils are heavy fine sandy loams grading through clay loam to silty clay at a depth of 40" (see appendix, profile No.2).

In the Eyraud association, seven distinct soils were recognised. The largest and most important are the Kanina soils which occur.

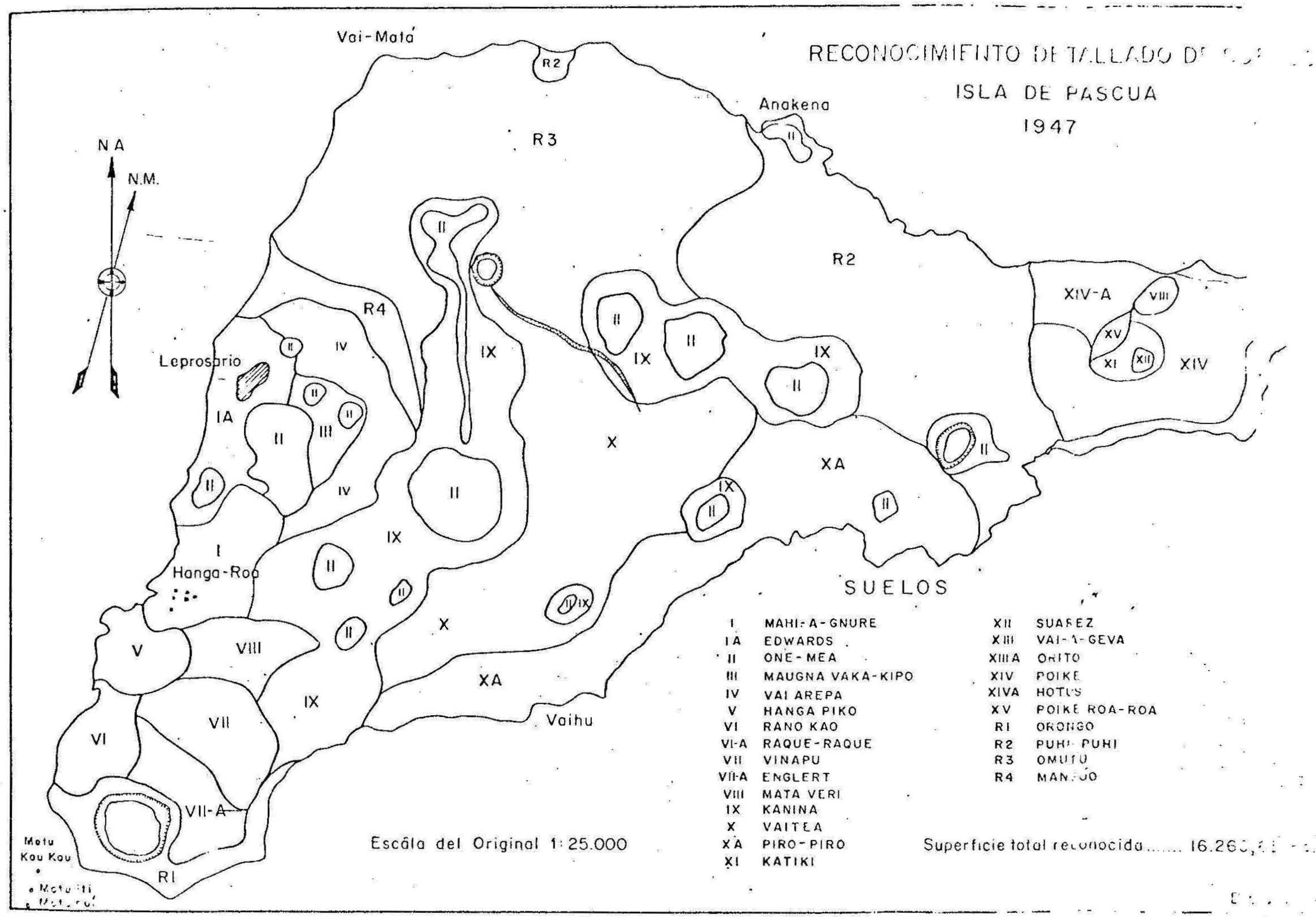


RECONOCIMIENTO DE SUELOS
ISLA DE PASCUA
1957
N.A.
N.M.
Vai-Mata
Anakena
V.R. Aroi
Leprosario
Hanga-Roa
V.R. Raraka
Poike
Vaihu
V.R. Kao
Motu kau kau
Motu iti
Motu nui
ASOCIACIONES.-
I Tolomiro
II Tea-Tea
III Hotu-Matua
IV Eyraud
V Toro
VI Mohai
VII Roggeween
Superficie total reconocida......... 16.260,63 Has.
Escala del Original 1:10.000

towards the centre of the island in two broad strips converging roughly at Rano Aroi crater. The related Suarez, Motus, Poike, Poike roaroa and Katikati soils are restricted to the slopes of Maunga Poike; while somewhat less closely related soils, Vinapa and Englert, occur on the north-east slopes of Rano Kao volcano. Kanira soils form the gentle (10-15%) slopes at the foot of many of the steep-sided scoria cones, and appear themselves to be of mixed origin, including scoria, tuff, volcanic ash and some outcropping lava. They are deep soils, commonly slightly stony but locally may have a mass of loose rock strewn over the surface. They are normally fairly heavy textured soils (clay loams to clays) and often of a pronounced reddish colour (see Appendix Profile No.3). Poike soils are deep silty clays, less red and more yellowish-brown in colour, and very rarely contain stones. (see Appendix, Profile No.4). Motus soils are very closely related to Poike soils but occur on somewhat steeper slopes (15-20%). Poike roa-roa soil occur only near the summit of Maunga Poike and are of moderately steep to steep relief (25% slopes). Suarez and Katikati soils are paler in colour, somewhat shallower than Poike soils, and occur on slopes of 15-20% and 20-30% respectively. In some features these last two soils resemble the soils of the Tea-tea Association. Vinapu and Englert soils are deep brown fine sandy loams developed on the flanks of the Rano Kao crater. Englert soils are developed on rolling topography and are locally stony; Vinapu soils on undulating landscapes and are usually free of stones (see Appendix, Profile No.5).

A large part of the island is mapped as belonging to a compound association, called the Mohai Association. This is a complex area, mainly hilly or strongly rolling with many broken slopes (slopes between 0-60%) and the soil consist mainly of close relatives of soils belonging to the Hotu Matua, Eyraud and Roggeween Associations. The Mohai compound association has four main facies: The Omotu facies of the association occupies most of the northern apex of the island and is predominantly a hilly region with many slopes of up to 30% and 40%; the Orongo facies which comprises the very steep slopes of Rano Kao crater; the Maungo'o facies which is a hilly region (slopes up to 20%) to the north and northwest of the Leprosarium; and the Puhipuhi facies which is a somewhat more gently lava plain with small scoria cones. The soil pattern is very complex and many of the soils are exceedingly shallow. Rock outcrops are locally abundant.

The Toro Association consists of soils derived from lava, most of which appears to belong to an earlier period of eruptions than those giving rise to the Hotu Matua soil association. Within the Toro Association there are four distinct soils. Mahi-a-gnure soils are developed on a sloping plain (5-6%) and are generally moderately deep clay loams, with a good structure and locally with a very stony surface. Vai-arepa soils are



RECONOCIMIENTO DETALLADO DE
ISLA DE PASCUA
1947
N A
N.M.
Vai-Mata
R2
R3
Anakena
II
R4
Leprosario
IA
II
III
IV
IX
X
XA
XIV-A
VIII
XV
XI
XII
XIV
I
Hanga-Roa
V
VIII
VII
VI
VII-A
RI
Vaihu
Motu Kau Kau
Motu Iti
Motu Nui
Escála del Original 1:25.000
SUELOS
I MAHI-A-GNURE
IA EDWARDS
II ONE-MEA
III MAUGNA VAKA-KIPO
IV VAI AREPA
V HANGA PIKO
VI RANO KAO
VI-A RAQUE-RAQUE
VII VINAPU
VII-A ENGLERT
VIII MATA VERI
IX KANINA
X VAITEA
XA PIRO-PIRO
XI KATIKI
XII SUAREZ
XIII VAI-A-GEVA
XIII A ORITO
XIV POIKE
XIVA HOTUS
XV POIKE ROA-ROA
RI ORONGO
R2 PUHI PUHI
R3 OMUTU
R4
Superficie total reconocida 16.26

developed on flattish relief (0-5%) mainly clay loams and clays with a very well developed granular structure, (see Appendix, Profile No.6), usually deep and only locally with loose stones strewn on the surface. Hanga pito soils are developed on an undulating plain (5-10% slope) and are mainly shallow and rocky loams with a good structure and a reddish brown colour. Mataveri soils are developed on a flattish to gently undulating plain (0-4% slopes), very stony and with many lava outcrops, and are shallow and of a light brown colour. It is suspected that the soil differences within the Toro Association are caused by differences in the type of rock in four different lava flows.

The Roggeween Association comprises two related soils. The One-mea soils are developed on the moderately steep and steep slopes of the many young scoria cones scattered about the island. The typical soil (see Profile No.7 in the Appendix) is a reddish-brown silty clay loam grading to a reddish-yellow clay at about 18" and changing to weathered scoria at about 24". The other member of this association, the Maunga-Vakakipo soils are developed on strongly rolling to moderately steep slopes and are reddish-brown clays of moderate depth (about 30" to weathering scoria).

The Tea-tea Association comprises two relatively unimportant soils derived from light coloured tuffs. Vai-a-geva soils are pale grey fine sandy loams grading to sandy clay loam at about

10 inches. Orito soils are dark grey fine sandy clay loams grading to pale pinkish grey sandy clay at about 15 inches (see Profile No.8 in the Appendix). Both soils are developed on 15-30% slopes, the Orito soils being located near Mataveri, and the Vai-a-geva soils on the north side of Poike promontory, at the opposite end of the island.

The soil map (Fig 12) accompanying this report is that drawn by Carlos Díaz V., in 1947, and it is about the best that can be made until either aerial photographs or a proper topographic map is available for the accurate plotting of soil data.

There are several other interesting soils to be found on the island which do not appear on the soil map because they cover only very small areas and their location is difficult to plot with any surely on the existing crude base maps. One such soil (see Profile No.9 in the Appendix) occurs over a small flattish plain below the outlet of Rano Aroi crater lake. This is a prominently gleyed soil which has been given the provisional name of Terevaka silty clay. This soil has a very dark grey topsoil, changing sharply to yellow brown at 9 inches depth, and thence grading yellowish red and pale reddish grey with prominent whitish mottling at a depth of 18 inches. The water-table occurs at a depth of 18-20 inches and is perched over pale yellow weathered volcanic tuff. Textures are silty clay throughout the profile. This appears to be the only soil in the island with an abundant worm population.

Peat soils are developed within the three main craters owing to the decomposition of the thick mat of floating reeds. These are veritably 'floating' soils, for they occur as a dense fibrous peat (see profile No 10 in the Appendix) to a depth of about 5 to 6 ft and below this depth they disintegrate and disappear in the humus-charged water of the lake. They have been provisionally named Rano Aroi loamy peat.

2. The Soil Process . The strength and direction of the soil process in Easter Island soils is not easy to evaluate. There are several conflicting phenomena to be reconciled. For instance, the total annual precipitation is not very heavy, yet all the soils are at least moderately, and in some cases strongly, acid. This could be taken as an indication that the soils are very old. This supposition conflicts with the widespread occurrence of quite deep soils whose textures range from fine sandy loam to silty clay loam. Moreover, with the exception of the soils of the Toro Association, strong acidity is a general feature of the island soils. It seems unlikely, on the field evidence, that all soils on the island are of equivalent age.

Erosion, and other processes of the drift regime are clearly very active in Easter Island soils. As mentioned earlier, the presence of material resembling volcanic ash could be explained by wind erosion of the soft andesitic tuff beds exposed along the cliff face and subsequent redistribution of this dust by both wind and water over the island landscape. The complete absence of any regular pattern to the distribution of the light-textured soils with clearly visible fragments of relatively unweathered volcanic minerals, combined with the absence of stratification in the profile are two reasons for postulating secondary (loessial, or alluvial) origin rather than primary origin by means of a local volcanic ash shower.

Moreover, many of the soil profiles show a sharp discontinuity between the lighter-textured topsoil and the clay subsoil, without any sign of clay skin development around the subsoil aggregates or in the pores of the weathering rock below. There is thus no clear field evidence of clay movement down the profile in the majority of the soils.

Spectrographic analyses of a number of soil samples was carried out by N. Wells of the New Zealand Soil Bureau. These provides some very interesting data but do not resolve any of the above anomalies. The spectrographic data (table 2) confirm that the soil parent material is predominantly andesitic rather than basaltic in nature. The total amounts of nickel and chromium are far lower than is normal for soils derived from basaltic rocks. The very high levels of titanium in all the Easter Island samples would be consistent with an origin from basaltic rock,

TABLE 4 - SPECTROGRAPHIC ANALYSES OF SOME EASTER ISLAND SOILS

(Analyses by N. Wells, New Zealand Soil Bureau)

Association	Series	T 0-6 in S 6-12 in	Al %	Fe %	Ca %	Mg %	Zr ppm	Cr ppm	Mo ppm	Ni ppm	Mn ppm	Co ppm	Ca ppm	Ti ppm	Ba ppm	Sr ppm	Cu ppm	V ppm
HOTU-MATUA	VAITEA	T	4.0	20	0.4	0.7	100	-	2	-	2000	25	30	10000	-	-	20	200
		S	4.4	21	0.4	0.7	100	-	2	-	2000	25	30	9000	-	-	20	200
	VAITEA	T	4.2	21	0.6	0.8	100	10	2	-	2000	25	30	7000	-	-	20	200
		S	5.5	21	0.6	1.1	100	20	2	-	2000	25	30	8000	-	-	20	200
	VAITEA	T	5.5	16	0.3	0.4	150	tr	2	-	2000	15	30	10000	-	-	20	100
		S	4.6	18	0.4	0.4	150	-	2	-	2000	15	30	10000	-	-	20	100
	VAITEA	T	3.8	20	0.4	0.7	100	-	2	-	2000	30	30	10000	-	-	20	200
		S	3.8	20	0.3	0.8	100	-	2	-	2000	30	30	10000	-	-	20	200
EYRAUD	KANINA	T	4.8	17	0.3	0.3	150	tr	2	tr	2000	15	30	10000	-	-	20	30
		S	6.6	18	0.4	0.3	150	-	2	-	2000	20	30	10000	-	-	10	30
	POIKE	T	4.6	19	0.2	0.3	100	30	2	5	2000	20	30	7000	-	-	50	200
		S	3.8	19	0.2	0.3	100	30	2	5	2000	20	30	7000	-	-	50	200
	VINAPU	T	5.8	17	0.2	0.3	150	20	2	5	2000	20	30	9000	-	-	50	100
		S	7.2	18	0.2	0.3	150	20	2	3	2000	20	30	9000	-	-	50	100
TORO	MATAVERI	T	7.8	15	0.6	0.4	150	-	2	-	2000	tr	30	8000	150	150	10	30
		S	7.2	16	0.4	0.5	150	-	2	-	2000	tr	30	8000	200	200	10	30
	MAHI-A-CHURE	T	7.2	17	0.8	0.5	150	-	2	-	2000	5	30	9000	500	500	20	30
		S	5.0	16	0.3	0.4	150	-	2	-	1000	tr	30	7000	200	200	20	30

but there are also andesitic magmas known to possess this feature, and, in any case, this high level of titanium could be the result of concentration by the drift regime. The total iron content of the soils is also very high, whereas the alumina content ranges from very low to normal.

The levels of calcium, magnesium, barium, and strontium are very low and thus in agreement with the field and chemical evidence that the soils are in the main, strongly leached.

It is interesting that both Poike and Vinapu soils of the Eyraud Association have slightly higher chromium, nickel, cobalt and copper levels than the soils of the other associations. These are the soils associated with the broad planeze slopes of the oldest geological formations on the island, and the earlier volcanic activity may well have been associated with more basic andesitic magmas. A second feature of interest in the spectrographic analyses is the clear separation of the extensive flow rocks which give rise to the Vaitea soils of the Hotu-Matua Association, and those of the more local flows that give rise to the various soils of the Toro Association. Not only do t the latter soils have a much higher pH, but they also contain higher levels of barium and strontium and very low levels of vanadium.

As yet there is no data available on the nature of the soil clay nor on the residual minerals present in the soils. When these aspects are investigated, some of the contradictory evidence may be explained.

A limited number of chemical analyses have been carried out under the direction of Sr. A. Rodríguez, in the Soil Laboratory of the Department of Conservation and Technical Assistance, of the Chilean Ministry of Agriculture, are shown in table 3.

Soils of the Hotu-Matua Association have a high cation exchange capacity (28-60 m.e.%) and are only moderately well supplied with organic matter. Exchangeable calcium is present in moderate amounts (5-8 m.e.%) and exchangeable magnesium in moderate to high amounts (2-4 m.e.%). Available potash is very high (0.03-0.15%) and available phosphate usually low in the subsoil, moderate in the topsoil. The percentage base saturation is low (30%) in the topsoil to very low in the subsoil (16%).

Soils of the Eyraud Association have a moderate to high cation exchange capacity; moderate to low organic matter content; low exchangeable calcium; medium exchangeable magnesium; high available potash and very low available phosphate. The % base saturation is low to very low.

Soils of the Toro Association have a moderate to high cation exchange capacity; low to very low organic matter content; high exchangeable calcium and magnesium; high available potash and high available phosphate. The % base saturation is moderate to high.

From the limited chemical analyses available there would appear to be confirmation that the soils are at least moderately-to-strongly leached, and, that the soils of the Toro Association are not so strongly leached and have a much better base status than all the other soils on the island. These chemical analyses, taken together with the spectroscopic data, suggest that the soils of Easter Island are, in the main, to be regarded as strongly weathered and moderate-to-strongly leached soils.

This represents the sum effect of the action of the soil process over an unknown interval of time. In this section of the report we are more concerned with the dynamics of the situation: the present trends and the varying rates at which the various processes are probably operating. It is necessary to try to evaluate the strength of current soil processes in order to be sure that any recommended systems of land development, soil rehabilitation, etc., are likely to be in tune with conditions actually prevailing in the soil. For example, we know that the soils are already leached, and we know that there is virtually no chance of controlling this through liming because there are no adequate sources of calcium carbonate available on the island. If the current rate of leaching is rapid then we are faced with a very serious agricultural problem; but if the current rate of leaching is slow and the acidity of the soil has built up slowly over a long period of time, or is due to some management factor in the recent agricultural history of the island, then the agricultural problems may be much more manageable. To evaluate successfully the strength and direction of the soil process is one of the most significant agricultural tools in the hands of the soil surveyor.

Taylor (1949) has divided the soil system, for purposes of analysis, into three interdependent parts:- the wasting, the organic, and the drift regimes.

The wasting regime include the processes of both physical and chemical weathering, together with further transformation and translocation of the weathering products and their eventual concentration in various soil horizons. On Easter Island, physical weathering ("comminution") is probably minimal because temperatures near freezing point are never experienced, and exceedingly high temperatures in the absence of moist air are likewise unknown. Chemical weathering ("argillisation"), on the other hand, could be very rapid because the background temperature is consistently high (about 75°F) and the air is consistently humid (over 80% relative humidity) for at least 20 of the 24 hours very day. On Easter Island, exposed outcrops of lava show only a thin weathering crust but the rock pores within are often softened and contain argillaceous material. As a layer of soil and vegetation develops the argillisation process accelerates rapidly. In most areas where there is a cap of 10 inches or more of soil, lava is rotten and decomposed to an equal depth. Most of the lava on the island is porous, - some lavas are exceedingly scoriaceous ('aa') and in these there is pronounced argillisation at depth.

During the argillisation process, nitrates, chlorides, sulphates become released and are translocated rapidly if there is any directional movement of water through the material. Calcium, sodium, magnesium and potassium likewise and released and have a relative mobility of 15:12:6:5 in the order shown. Oxides of silica are about five times as mobile as oxides of iron, and the latter are twice as mobile as oxides of aluminia, and all of these are essentially by-products of the process of argillisation. During argillisation, water may re-distribute the end products or any of the intermediate products, over a varying distance through this soil profile. These associate processes include loss by solution ("leaching") and loss by translocation of colloids ("illimerisation"), and both process may lead to eluvial or illuvial concentrations that may result in the formation of indurated or cemented horizons or 'pans' in the soil profile. The rocks of Easter Island are not particularly rich in silica and appear to lack quartz crystals (no accumulations of quartz grains occurs anywhere on the island). Some magnetite and titanium sand can be demonstrated by washing the soil clay, and, in general, it would appear that the process of argillisation is far advanced in all soil material formed directly from the country rock 'in situ'. The process of weathering in this material is virtually complete, and the current rate of argillisation of unweathered minerals introduced into the soil is likely to be high. This is an important conclusion for, on an isolated island with no specific fertilizer deposits, a satisfactory means of improving the plant nutrient supply may prove to involve nothing more than crushing the local rock and mixing this with the surface soil. Nature will do the rest and bring about a release of calcium, potash and some other elements required for plant nutrition.

The mechanism by which the weathering products are moved through the soil involves a supply of water in excess of that needed to simply fill the fine pores in the soil. Condensation of dew at night dampers the surface soil but does not cause a downward movement such as occurs when rain falls on the soil. On Easter Island the total annual rainfall is only of the order of 50 inches, and possibly as much as one-third of this is lost by evaporation soon after it falls on the soil. Pratically all the rain falls in the form of heavy 'tropical' showers and the water does not penetrate rapidly into the soil. It is always assumed, because the island consists od porous rock, that the rainfall passes rapidly in the soil but it may be clearly observed that after a heavy shower of only a few minutes duration, pools of water lie on the surface of the soil for several hours. The upper part of the soil becomes saturated rapidly but the heavier clay of the subsoil accepts water slowly, particularly if in a rather dry condition previous to the arrival of rain. In many areas, there is more lateral than vertical movement of water, - and this is one of the chief causes of the spectacular erosion which is steadily destroying the mantle of soil on the island. Thus, with regard to leaching and illimerization, the current processes are probably not such rapid ones as might be expected, and the strongly leached condition of the soil must be ascribed to either age or to some other factor. There is little evidence of clay movement in the soil profiles at the present time and there is no accumulation of weathering products in the form of soil 'pans'. The significance of this evaluation is that, if systems of soil management involving the use of fertilizers are applied on the island, losses due to leaching need not be serious.

The organic regime is the medium by which energy is built into the soil system. It is the introduction of life processes amongst the chemical and physical processes in the developing soil, and, in general, soil life struggles to mantain adequate living conditions in the face of the exhausting effects of the wasting processes. Soil life not only adds carbon and nitrogen to the soil, but these elements are usually combined in such a way that the organic compounds promote the retention of water, cations, anions; and possibly even some gaseous compounds, - exerting a profound, although sometimes temporary, effetct on soil aggregations, soil moisture and soil air. Moreover, elements of the soil mineral system caught up in the organic regime are protected from the processes of the wasting regime for the duration of their association. In the case of deep-rooted plants and trees, the organic regime goes further and brings elements that have already been lost from the upper horizons of the soil back to the soil surface. One of the most significant features of the organic regime is that it basically depends upon the process of photosynthesis in plants growing on the soil, and when the dead plant tissues become incorporated in the soil, there is an energy release which may condition the process of argillisation and many the soil processes stemming from argillisation. Another important aspect of the introduction of life processes into the soil is that it promotes movements and mixing within the soil and between surface and the soil layer adjacent. To some extent the organic regime provides a buffer from extremes and a protection from sudden fluctuation in moisture and temperature. The organic regime exerts a moderating influence. There is a close parallel, and sometimes even a close relationship, between the organism in the soil and the livestock living above the soil: a soil deficient in organic matter and with a reduced micro-organism population is unlikely to support large numbers of farm livestock. Many of these features are well illustrated in Easter Island soils.

One of the striking aspects of soil genesis on Easter Island is the fact that the island soils have never as far is known supported a dense forest vegetation, despite a climate well suited to tree growth. As mentioned earlier, this is probably an accident of isolation but it has exposed the soil to a long interval of weathering without the counter-benefits of a strong mechanism for re-cycling plant nutrients. Most grasses are less effective than trees in this respect, and one of the reasons why Easter Island soils are so markedly leached is probably to be found in this environmental anomaly. Not only have the soils been deprived of the potentail ameliorating influence of a forest cover but the natural grass communities have been kept at a level of low organic return by almost a century of poor management involving excessive grazing and burning. The soils still have some organic matter and probably have a fairly vigorous (but atypical) micro-population; but the efficiency of the organic cycle has been gravely impaired by unwise soil management. At the present stage, over 90% of the island is occupied by plants which neither demand nor expect a high level of soil fertility. Such plants - typified by Sporobulos which is dominant in the induced pastures - neither take much out of the soil nor return much to the soil. The regular burning of the grass sward only serves to short-circuit the soil organic cycle and convert organic compounds to a soluble mineral from which can be quickly washed away by the rain. Since much of the rainwater moves laterally in the soil, these potential plant nutrients are largely lost to agriculture. The quantity of humus annually accumulating in the soil is clearly low, but

The quality of this humus is likely to be very poor indeed.

With this breakdown in the very essence of the organic regime, other disastrous effects follow. For one, the buffering and insulating properties of the soil system are gravely weakened. Easter Island soils are remarkable for their high subsoil temperatures (86° F at a depth of 10", on some days). In place of an insulating layer of vegetation, the soil has developed a tight sod-bound topsoil, bound together with grass roots which rarely penetrate below 8". The subsoils are practically untapped by plant roots and the re-cycling of nutrients becomes progressively weaker with the passage of every additional year that the present system of soil management continues. Machanical mixing within the soil is at a minimum: earthworms have long been absent in the soil over most of the island; and as the soil steadily increases in compaction, pore space diminishes and erosion accelerates. This would be serious in any soil but on Easter Island, where most of the soils are strongly weathered and the reserve of unweathered minerals is often very low, the net effects of a weak organic regime is to produce a condition approaching sterility. The soils of Easter Island are not far off the point where the main reserve of plant nutrients is that which is being cycled in the organic regime. Further weakening of the latter will result in the production of a pedologic peneplain or - from the farming point of view - a desert. That this has not yet already happened may, in part, be due to some recuperative influences associated with the soil drift-regime.

The drift regime embraces the mechanical disturbance of the soil system by inorganic agencies. This includes the mechanical processes of erosion (downslope movement aided by gravity, translocation by wind and water); accumulation (motivated by gravity, air or water), and mixing due to expansion and contraction of the whole soil mass or that part near the soil surface.

Soil movement is extremely active on Easter Isalnd. In the main, this is due to the greatly weakened natural plant cover, but in part it is due to the advanced stage of soil weathering which has produced clay mantle not readily penetrated by water. Evidence of sheet erosion may be seen everywhere and in many areas tunnels and gulleys are dissecting the landscape. Slumping and slipping are common on all the steeper hillsides. This high degree of instability was set in motion when the original vegetation of the island was first burned, and the erosion has steadily accelerated during the years of over-stocking with sheep and the frequent burning of the grass to induce new shoots to feed the excessively numerous sheep population. In many areas, there is little that can be done except to plant trees, - and in some areas (e.g. on part of Poike promontory) it is even proving difficult to establish Eucalyptus plantations. Normally rapid erosion brings some fresh rock minerals to the soil surface and this at least assures an increase in the plant nutrient supply in the derived soils. This, however, does not always occur in the humid tropics, on landscapes formed from andesitic and more basic rocks. The weathering processes can be so rapid and thorough, that erosion releases and distributes mainly material that has already lost most of its unweathered mineral reserves. Although Easter Island is not within the tropics, the rate of soil weathering may well approximate to that of tropical soils, and so accelerated erosion brings little relief to the struggling vegetation.

There remains to be considered the light textured often somewhat sandy, material that so commonly overlies, or is intermingled with, the clay soil mantle of the island. Reasons have been given stating why this might be a local aeolian deposit, as distinct from an actual volcanic ash shower; and origin as dust abraded from the naked tuffaceous cliffs has been postulated. Whatever its true nature and origin, it is almost certainly associated with the soil drift regime; - and yet its influence on the fertility of the soil appears to be almost negligible. This may in part be due to the fact that the tuff beds exposed in the cliffs are already highly weathered before they are attacked by the wind, and in part due to the winnowing effect of the trade wind which soon drops most of the larger particles and distributes mainly only the finer fractions. In soil profiles that show a clear break between the clay subsoil and a lighter topsoil, the latter differs but little chemically from the subsoil, apart from a slight increase in the calcium, magnesium, potash, and cation exchange capacity and a decrease in available phosphate. This would be in accordance with a slight augmentation of fine mineral particles, the volcanic glass portion weathering to allophane which would raise the cation exchange capacity and cause increased phosphate fixation.

Enrichment of soil by efflorescence of the waterable ("flushing") does not occur on Easter Island, but there is clearly some enrichment of the strip gleyed subsoil below the overflow from Rano Aroi crater lake. Here are found permanently moist, apparently fertile, soils that carry a thick grass cover (despite the frequent burning), and the soils have a very high earthworm population. There are no examples of earth movement caused by melting and drying, or by freezing and thawing, anywhere on the island. Mixing due to wetting and drying depends on the presence of expanding clays; these are not formed in any quantity on Easter Island.

To sum up this section on the soil processes most active on Eastern Island:-

(i) The relatively rapid rate of rock decay can probably be turned to good use to release plant nutrients from final crushed rock mixed with the soil. This might obviate the need for transporting lime and potash to the island.

(ii) The relative slow rate of leaching makes the use of nitrogenous and phosphatic fertilizers feasable; although it would be better to emply legumes to incorporate nitrogen from the air into the soil. Phosphatic fertilizers are unlikely to be profitable to use, unless the soil organic regime is first built up.

(iii) The soil organic regime is functioning weakly and the highest priority should be given to the introduction of inexpensive systems of soil management that will rebuild the faltering soil organic cycle. Under the environmental conditions prevailing on Easter Island the soil organic regime must always be the chief guardian of soil fertility and plant nutrient reserves.

(iv) Erosion, so conspicuous in many parts of the island, is a result of ill-adapted farm management and the only cure is to plant the most seriously destroyed and potentially dangerous areas in trees.

C. Land Use and Agricultural Development

1. Land Use: Since the year 1936 the Chilean Navy has been responsible for the administration and progressive development of Easter Island and its inhabitants. Although greatly restricted in scope by rigid financial limitations, and with inadequate technical assistance, the Navy has nevertheless tried very sincerely and had considerable success in improving living conditions on the island. Unfortunately, the Navy has had less success in discovering an economic basis upon which development of the island might be continued.

It is not surprising that some of the technical aspects of this task proved to be beyond the ingenuity of the Navy to solve them, for the problems are truly formidable.

From time to time the Navy have invited technical experts to the island for brief visits, to study specific problems on the spot. Thus, in 1960, alarmed at the deteriorating conditions of the sheep industry on the island, Arthur Delley of the F.A.O. Technical Assistance Mission was invited to report on the livestock and pasture problems. The Delley report (23) advised numerous changed in livestock management practices and emphasised that increasing attention should be given to pasture and livestock improvements. Similar recommendations were made by Hrepich (24) of the Ministry of Agriculture. Subsequently the Ministry agreed to the appointment of a resident agronomist to take charge of the pasture improvement experiments, while the Navy concurred in the appointment of a skilled practical and technical farm manager for the sheep ranch.

skilled practical and technical farm manager for the sheep ranch.

The production of wool is the main source of income for the island, but in addition to comments on improvements required to maintain and increase wool production, both the above experts commented on the need to guide and assist the islanders in the production of more useful 'export' crops on their individual farms. The recommendations in this field were less specific but sufficient was said to indicate that little advantage seemed to be taken of the unique climatic conditions prevailing in this remote outpost of the Republic of Chile.

The earliest recorded systems of land use on Easter Island made a considerable impression on the Early Navigators of the Pacific Ocean. Behrens (loc. cit, p 135) mentions crops growing in fields whose regular shape was achieved by the use of a measuring cord. Roggeween (25) described the principal plantations and orchards as being in the south-west sector of the island, that is to say in the vicinity of Rano Kao and Mataveri. Hervé (26) records plantations and gardens of large extent, growing sugar cane, sweet potatoes, taros, yams, white gourds and various fibre crops. Forsten (loc. cit.) mentions that in some areas bananas were planted in holes 1 ft deep to collect rain and conserve moisture. La Perouse (loc. cit., Vol 2 p. 332-333) formed a high opinion of the fertility of the soil and estimated that only about 1/10th of the island was actually under cultivation. He also comments on the great skill with which the plantations were laid out in 'rectangles and long squares', and farmed without enclosure. Beecher (loc. cit. p. 42) gives us some amplification of the pattern of cultivation for he states that the islanders preferred places not directly exposed to the rays of the scorching sun (i.e., presumably, the shady slopes and shaded side of local depressions in the lava plain) and that they worked the soil into furrows at right angles to the slope, the better to hold the rainfall. He also mentiones food gardens above the bay of hotu-iti, (near the north cape) where a small crater formerly breached by the sea was planted in bananas. From these, and other historical records, it is apparent that the islanders used mainly the deeper and more sheltered soils, but for some crops, also employed the hill slopes, and even the tops of the hills. There are no indications in the present landscape to show exactly where these old garden and orchard areas were located, but frequently signs of former cultivation are encountered in soil pits dug for soil profile studies.

The art of agriculture declined during early part of the 19th century when internecine warfare and cannibalism was rife on the island and the earliest missionaries recorded a very different state of affairs to that seen by the first european sailors (27). At this time, the various tribal lands were long narrow strips running from the coast island. Although clearly marked along the coast, the inner limits of each tribes' land were somewhat vague, and the centre of the island was a sort of nomans land, - a refuge for outcasts and survivors of vanquished tribes (28). By 1868, the Missionaries had been successful in converting all the islanders to Christianity and in 1888 the Government of Chile laid claim to the island.

Before the declaration of Chilean sovereignity over Easter Island, several private individuals had purchased land in the Island and made a start with agricultural development. The largest of these ventures was that belonging to a Society formed to develop a sheep and wool industry, in the year 1871, and comprised an area of some 2275 has. Probably the animals were allowed to range over most of the island. These early flocks may not have greatly exceed 5000 head, but their presence on the island at this time shows that sheep have been exerting an influence on the islands vegetation and soil for only a little short of 100 years.

Following the declaration of Chilean sovereignity over Easter Island, on 9th September, 1888, the earlier land purchases were re-examined but in 1895 most of the fiscal land of the island was rented to another sheep-farming company; and on the expiry of this lease in 1915, the system was continued under a new agreement, and eventually came under the control of a very large sheep-raising company which closely integrated operations on the island with various large properties which they owned on the mainland. It is claimed that the sheep carrying capacity of the island soil was pushed up higher and higher towards the final years of the lease. Eventually, in 1936, the Chilean Navy inherited the sheep industry. Many of their problems at the present time spring from the earlier damaging years when natural pastures were overstocked and overgrazed. The extraordinary amount of soil erosion on the island problably also dates from this period of the island's agricultural history.

One of the most damaging factors associated with sheep grazing has been the use of fire as a mean of getting rid of dry, unpalatable grass and inducing soft greet shoots. Periodic grass fires almost certainly commenced with the arrival of the first Polynesian colonists. Grass fires were reported by early voyagers, such as Lisjanski, in 1812 (6), and again by Beecher in 1831 (loc. cit); but regular and systematic burning of the natural pasture commenced in earnest from 1916 onwards. The original mixture of grasses on the island has steadily changed until only the poorest and most persistent species now remain. There is now no sign of the Paspalum referred to as 'Jamaica grass' collected by Dr. Forster, Captain Cook's botanist, in 1773 and many of the grass species noted by Skottsberg in 1918 appear to have since died out. The dominant grass Sporobolus, is a plant which might well rank as a noxious weed for all nutritional value as sheep pasture. The situation has now reached the stage where it is impossible to keep sheep alive on the island unless frequent burning of the natural pasture is carried out. Thus, a highly anomalous situation has arisen, for Easter Island was declared a National Park and Historic Monument as far back as 1935. Unless radical changes are made in the policy of using some four-fifth of the island as sheep range, the final result will certainly be the deliberate destruction of a declared National Asset.

An additional source of soil depletion has been unwittingly fostered by the Chilean Navy in their efforts to get the island on a sound economic footing. To sustain the pig industry, the Navy encourages the growing of maize by the island farmers. Maize is the only cash crop available to the islanders, and as a consequence maize is sown repeatedly throughout the year; often several successive crops are taken from the same area of soil. Naturally this leads to rapid exhaustion of soil fertility and, since each married islander is entitled to only 5 hectares of fiscal land, the more energetic farmers have reached the point where they have mined all the available plant foods in their allotment and are now applying to exchange their land for a new parcel of 5 hectares. This amounts, very nearly, to legalised shifting agriculture, and is a very bad thing indeed for the agricultural future of the island.

Thus the two major forms of land use currently being practised on the island are distinctly detrimental to the future of the island. The only places where the soils were showing reasonably maintained fertility were under the orchards near the houses, and under the eucalyptus and other plantations established during recent years.

There is no question about the NEED for planting more trees on the island. The climate is very well adapted for tree growth and it was only an accident of isolation that prevented the island from having as luxurient forest cover as Tahity or Juan Fernandez, or any of the other Pacific Islands in even cooler latitudes. This was the opinion of Professor Skottsberg, who also considered that the island probably originally supported a forest-savanna type of vegetation, with considerably more forest than reported by the first European visitors. This opinion is supported by an examination of the soils. In very many of the soil pits, there is a thin layer of very fine carbonised wood fragments immediately below the uppermost part of the soil which is derived mainly from accumulation of erosion products. The carbon layer may occur at a varying depth in the soil profile, depending upon the local rate of soil accumulation, but it is so widespread that one is tempted to imagine that almost three-quarters of the island may once have had some type of wood shrub or forest cover.

To control erosion, and as an aid in the conservation of the water reserves of the island, trees should be planted on all slopes over 15°. This policy might well be extended to include some of the very rocky, lowlands areas of gentle relief where pasture growth is restricted to less than 50% of the surface owing to efflorescence of lava rocks. Eucalyptus appears to be a very fast-growing tree under island conditions, but it may not be the best tree with regard to conservation of moisture. Other tree species with lower transpiration rates should be sought and tried out on the island.

Summing up the current land use problems of the island, the following points need attention:-

1. Sheep farming based on open range management can no longer be recommended without very serious consequences for the future. Previous experiments with introduced grasses and clovers scattered amongst the native grass have shown few satisfactory results.

Clearly the soils are no longer able to support demanding and nutritious species without the assistance of fertilisers and careful livestock management. The best management system would be to gradually withdraw the sheep industry to two or three selected areas where high quality fertilized pastures and adequate shade trees can be established in advance.

2. The pig industry operated on behalf of the island by the Navy is barely an economic proposition, and since it has become an incentive for exhaustion of the soils on the family allotments it would be better abandoned, or drastically modified.

3. Preliminary attempts at afforestation are very encouraging, and this aspect of land use needs rapid expansion to help in the control of erosion and to provide better protection of the islands water supplies.

If the land use policy in respect of Easter Island is modified to conform with the above suggestions, there will obviously be very serious repercussions to the islands's economy. The change from extensive to intensive sheep farming must involve a reduction in sheep on the island; hence a period of lower returns from wool which will coincide with the period when money is needed for pasture establishment, fencing, tree planting, and purchase of new livestock. If at the same time, there is a tapering off in the pig industry, it will certainly cause added hardship to the islanders. At the moment the Chilean Navy is keeping the island economy close to the break-even point, but the effects of bad land use are cumulative, and every year places the Navy in a more difficult position.

There is absolutely no doubt that a new agricultural policy is urgently needed for Easter Island, but before proceeding to consider the lines which an agricultural development programme might follow, it is valuable to consider some of the special features of the island environment that must have a powerful influence on agricultural development.

2. Special features of the Easter Island environment that must influence the use to which the land can be put:

a. Isolation and lack of transport to Continental Chile

Progress in airport construction is delayed because of the very real difficulty experienced in laying an adequate concrete strip on an island which has no quartz sand, no satisfactory gravel, no good site for quarrying and inadequate water supply for part of the time. Cement and most of the sand and gravel have to be shipped in the annual supply ship which has severe cargo limitations. Nor will an airport solve the problem of shipping large quantities of perishable agricultural produce, as pineapples and bananas, even if transport costs were subsidised.

To support a more frequent shipping service and maintain it on an economic basis likewise seems out of the question at present, - at least until such a time that the island achieves a much higher standard of agricultural production. Transport limitations virtually restrict agricultural production to crops that can withstand up to one year in storage in the raw condition, or to crops that can be partially or completely processed on the island.

In the former category belong dried fruit, nuts, beans and certain spice crops. Coffee berries might also be in this group. Processed crops included canned fruits and fish, and possibly expressed vegetable oils and prepared fibres.

b. Limitations of Land and Labour

Cane sugar and canned pineapples are frequently mentioned as possible export crops (e.g. 23,24,30), but even under the most favourable circumstances a small factory specialising in these products could not hope to compete with large established firms outside Chile. On Easter Island, conditions are far from favourable since the area of soils on which these crops might be grown is relatively insignificant; moreover the abundance of stone and rock makes mechanisation all but impossible in many areas. Moreover the labour force on the island amounts to less than 300 able-bodied men and women. Lack of suitable land and the small labour force available is also an argument against establishing coffee plantations of any worth-while size.

c. Water Supplies

There is little doubt that scarcity of water on the island is only a temporary problem and that when deep wells are dug at some distance inland from the coast, the supply of fresh water will be adequate for the human and animal population and probably quite adequate to support small industries, should these eventually appear. The immediate programme for improving water supplies should include well-digging, pipeline reticulation and installation of pumps.

d. Soil Conditions

i. Soil fertility. In general, the fertility of the soils of Easter Island may be considered to be low, rising to moderate in the case of the soils of the Toro Association. Most of the soils in the island cannot be expected to support intensive farming (either crop production or grazing) without some improvement in their plant nutrient status. It is obviously out of the question to transport artificial fertilizer in adequate quantity from the Chilean Mainland and alternative systems will have to be devized.

The brief study made of the strength of the soil processes operating under the island's environment suggests that one way of replacing many of the missing plant nutrients will be to virtually invert the soil profile by using the crushed rock as a topsoil ameliorant. This will become possible as soon as rock-crushing facilities are available on the island. Similar experiments with 'quarry dust' from basaltic rocks were carried out in New Zealand during the last war, and, in the main, proved successful.

Additional of finely crushed rock and rock dust to the top-soil will improve the plant nutrient status but will still leave a deficiency of available phosphate and of nitrogen. Nitrogen can be built into the soil by means of growing legumes but it is almost certain that the legumes will prove impossible to establish so long as the soils continue to have a very low available phosphate status. Thus, it is very probable that some form of phosphate will need to be added to the soil before the nitrogen deficiency problem can be solved.

It is unfortunate that the sea-birds have largely deserted the Easter Island rockeries, both on the main island and on the small rocky islets. There is no adequate source of bird guano in the area. Since the low rocky Salas y Gomez islets, some 300 miles to the north-east, are too lowlying, and are largely swept clean by storm waves, there is no guano to be obtained from this locality either. Many of the underground caves of Easter Island contain an accumulation of organically rich soil on their floor. This soil probably contains some phosphate, but the quantity of cave soil available is too limited to serve as a general source of agricultural phosphate. The amount of seaweed available is likewise limited and difficult to secure. The only major local source of phosphate is in the fish of the sea, and there no longer exist any facilities for converting fish into fish-meal which could be used for supplying phosphate to plants, and protein with phosphate to animals. Some 30 years ago a small fish-meal plant was in operation on the island and this, together with crushed bones from slaughtered livestock, was added in one form or another to the island soils. Unless this fish-meal industry can be revived, there will be no alternative but to transport artificial phosphate fertilizers to the island, in sufficient quantity to act as a 'priming' for the establishment of leguminous species. In this eventuality the only phosphatic fertilizer that should be considered is the form known as 'triple phosphate' which carries the highest phosphate content per bulk density and can be obtained in a coarsely-ground or pelleted condition, which will reduce the amount of phosphate lost by fixation due to active soil processes.

All the normal nitrogen requirement of the island soils can be supplied by leguminous plants acting in partnership with soil micro-organisms. The phosphate is needed as much by the latter as by the legumes, but once the phosphate deficiency is overcome, the plant-microbe system can be expected to build atmospheric nitrogen into the soil. Alfalfa and subterranean clovers are currently under trial, but in future years taller sub-tropical and tropical legumes, such as kudzu, should be tried. There is a local bean (Vicia sp) which grows well, and which could, with advantage, be seeded far more widely.

The whole success of the phosphate and nitrogen programme, hinges upon the introduction of systems of soil management that will conserve and build up the soil organic regime. Under Easter Island conditions, it is absolutely essential to build up the soil humus and keep the organic cycle operating at as high a level of activity as possible. To avoid unnecessary destruction of soil organic matter by intense insolation, the soils should be managed in such a way that they have a nearly continuous plant cover of adequate depth and thickness to give protection from direct sunlight and from rapid heating. Easter Island soils should, as far as possible, be kept covered from the direct rays of the sun at all t'

There is no question that, provided with a only minimum quantity of imported phosphate fertilizer and management aimed at conserving soil humus, the fertility of the soils of Easter Island would be greatly improved. However, they could not be improved to the level where all types of sub-tropical and warm-temperated crops can be grown. Because of the limitations of the natural soil processes there must always be some control exerted by the soil over the type of crops that can be grown. A list of potential crops which could be grown for 'export' from the island has to be culled to exclude all crops which demand high and continuous supplies of P, N, Ca and, probably K.

ii. Soil moisture. A further limiting factor, associated with the soils is the supply of adequate moisture for the growing crops and pastures. Crops which require a very high and almost continuous supply of soil moisture could not be grown economically on Easter Island.

Easter Island soils are periodically subject to a high rate of evaporation, to high soil temperatures and to periods of drying out to a depth of 18-24 inches during a prolonged drought. There are various ways of minimising this. The oldest, and that used by the ancient Polynesians in many other islands, is to keep the unused surface of the soil covered with a 'mulch' of loose stones. Flat stones are better than round stones and the surface layer should be at least 6 inches in thickness. Mulching the soil surface with dead organic residues is a better known techniques and is better for the soil in that it leads to the incorporation of extra organic matter but on the island there is a dearth of these residues. The stone 'mulch' technique could well be employed on Easter Island for permanent orchard crops. So great is the need to conserve soil moisture in Easter Island soils that every available system should be tried.

With the development of wells for exploiting subterranean water supplies, some irrigation may ever become possible on the island, and this will considerably lengthen the list of crops that could be grown with security on the island.

e. Potential crops and how to stimulate production

The problem of pastoral farming is mainly one of establishing good grass-legume swards in certain parts of the island where adequate water is available for livestock, and managing these units with care and intelligence. The problem of selecting suitable economic crops is complicated by the problem of transporting produce to the mainland and the limitations imposed by soil and soil moisture conditions, by the limited area of suitable soil, and by the limited labour force available.

Fresh fruit have no 'export' possibilities and neither does canned fruit, unless heavily subsidised on a protected market. Sugar cane could be grown but only in quantities sufficient to support a small rum distillery. Cotton and fibre crops,(also coffee, cocoa and tea) all need a bigger labour force and would soon come up against the problem of lack of suitable soils for expansion of the industry. For maintaining soil fertility, a leguminous crop would be preferred. For ease of storage until the annual boat arrives, a dry fruit such as a nut should be selected. Something along the lines of a peanut growing industry would be ideal but the price of this commodity is probably not high enough to make this industry truly economic under island conditions. Also mechanization would be almost impossible in view of the large area with outcrops of lava rock.

Growing a nut crop for local extraction of oil has considerably better possibilities. Castor-oil is already under trial on the island and may prove to be the best of this category since it is adapted to fairly low nutrient levels in soil. Aleuroites (Tung oil) is another nut crop of this group which might be worth trying, although it needs rather better soil conditions for economic levels of production.

High-priced spice or essential oil crops are another field worth exploring. Nutmeg would probably not succeed owing to its soil fertility requirements; but high-grade ginger, tumeric, and other root-spice crops could be grown.

Best of all would be a dense-shade type of tree crop, one which would combine all the other desirable features. It is doubtful if cloves would do well in Easter Island soils, but tonka-bean trees should be tried, even though the world market is small. Selecting the ideal "export" crop for Easter Island will require ingenuity and some patient experiment.

There is only one way to stimulate the production of the desired selected crop:- by paying cash immediately for every single lot offered. With the passage of time, quality can be made a ruling factor but at the outset, it is production in quantity that will need to be encouraged.

A possible development programme:

In the situation outlined in the foregoing pages, and bearing in mind that there are also economic problems in continental Chile which preclude any sudden heavy expenditure on Easter Island problems, the logical suggestion to make is one which envisages a slow, steady, phased programme covering a period of say, ten, year.

The following suggestions are offered:-

10-YEAR PROGRAMME FOR THE AGRICULTURAL DEVELOPMENT OF EASTER ISLAND

1st. Phase - 1962-1964 : Investigation and experiment

1962 - 1) Development of Vaitea Experimental Station as centre of pasture (grass and legume) trials with varying amounts of fertilizers, minor elements, etc.

2) Establishment of forestry nursery at Vaitea.

3) Investigation of problem of small farmers; catalogue of actual crops and tree grown; collection of data on crop yields as index of soil fertility; list of insect and other pests causing diminished yields.

4) Observations and limited fertilizer experiments with potential new crops such as Castor oil, Peanuts. Establish a plant introduction nursery.

5) Programme for improving health of existing livestock.

6) Careful subdivision and repair of stock fences of areas Vaitea Rano Aroi - Poike and Rano Rao.

7) Establishment of a permanent technical committee in Santiago to deal with agricultural development problems of Easter

island. This committee should maintain radio contact with the resident agronomist on the island every other month.

1963 - 1) In the light of results obtained during 1962 experiments, pasture trials should be intensified and more extensive areas sown with promising seed mixtures accompanied by appropriate fertilizers. The cost of the pasture establishment should be carefully recorded. Up to 50 has. of promising seed mixtures should be sown and grazed by a special experimental herd selected from the main island flock.

2) Expansion of plant introduction nursery and introduction of a wider range of potential economic plants. Seed of potential crops can be gathered with the help of FAO and other international organizations from regions where similar climatic and soil conditions prevail (i.e. Northern New Zealand some Pacific Islands and northern islands of Caribbean region). Concentration upon crops which can be stored (i.e. nut crops from which oil can be expressed as Aleourites) edible nut crops, (as peanuts, cashew, pecan); spice crops, (as ginger, tumeric, cloves, nutmegs); coffee and possibly cocoa. Commencement of first phase in a programme designed to show small farmers how to get better results from their land; fertilizer demonstrations, etc.

3) Expansion of forest nursery and start of limited afforestation programme on land of over 20° slope: introduction of special

wind-resistent erosion control species (i.e. Ngaio, Pohutakawa, etc., from Northern New Zealand) for eventual planting severely eroded areas of Poike peninsula.

4) Aerial photography of the island and preparation of air mosaics with ground control: preparation of accurate planimetric map of island. A light plane or helicopter suitably equipped for aerial photography could easily be carried to the island on the "Pinto".

5) Reduction of sheep population by 15% of present total, and withdrawal of best part of flock to three areas (Poike, Rano Kao and Vaitea-Rano Aroi) when fences have been repaired and paddock subdivision carried out. Rigorous flock classing programme and inspection of animal health.

6) Inspection of air photographs and planimetric map by Easter Island Technical Committee; correlation of existing soil and other maps to determine general lines of zoning of island in three land use categories; assembly of all existing data on island's natural resources; and preparation for expedition of scientists to visit island for three months in 1964.

7) Use of air photos and base map to plan future limits of sheep farms and subdivision fences.

8) Selection of sites for three exploratory wells to be sunk towards the centre of the island to prove the depth and extent of subterranean water supplies.

1964 (In this year special transport arrangements are recommended to allow for expanded scientific work on the island and for the completion of such technical projects as well digging and drilling to explore the subterranean water reserves).

1) Three-month visit to the island by members of the Easter Island Technical committee and co-opted members specialising in plant ecology, entomology, parasitology, soil conservation, forestry, livestock selection, etc. Final selection of three localities for intensive sheep raising. Delimitation of permanent boundaries for limit of sheep grazing, for afforestation, and for agricultural development by island small farmers.

2) Review of experimental work carried out at Vaitea and selection of most successful grass and legume mixtures to be sown on sheep far areas. Establishment of 500 has. of improved pasture on two of the three selected sheep farms.

3) Reticulation of water from central wells to town and to newly established pastures; construction of additional fences etc.

4) Reduction of original sheep flock to 50% of original total and restriction of all remaining sheep to permanent farm (No. 3) on Poike peninsula. At this stage all sheep on island restricted to Poike, and given very thorough classing and vetting for parasites.

5) Handing over of re-afforestation programme to Forestry authorities; establishment of priorities for eroded areas requiring afforestation.

6) Review of plant introduction work carried out on island and selection of crops which seem to have most promising economic future; establishment of fund to guarantee purchase of all seed offering on island; organization for collection and distribution of seed.

7) Expanded aid to island farmers; assistance in planning family holdings; soil survey of area allocated for small farm development; re-designing and expansion of areas allocated to small farmers where soils exhausted; programme for rebuilding soil fertility in certain areas; establishment of better facilities for collecting and processing 'export' crops.

8) First step in reduction of pig industry leading to reduced requirements of maize for pig feed; introduction of quota system in maize production. Exploration of alternative and more nutritious crops which could possibly be grown as pig food.

9) Purchase of nucleous of future sheep flock for island; build up, on continent, of sheep of good quality for dispatch to island in 1965.

2nd. Phase - 1965-1968: Expansion of Development Programme

1965 Establishment of two new flocks of sheep on the land previously prepared at Vaitea and Mano Mao; close attention to stock management land livestock health; trials with conservation of fodder in form of silage and hay. Continue seggregation of remnants of former flock on Poike peninsula and begin pasture improvement programme on this farm with sowing 100 has of pasture and legume seed with fertiliser. Continue afforestation programme. Legislation totally prohibiting the lighting of unauthorised fires within afforestation area. Inauguration of cleared fire-breaks and fire patrols. Intensify small farm production by means of credits and fertiliser supplies.

1966 Continue development along same lines. Shipment of first bulk 'export' crops to coincide with further reduction in maize grown as pig feed; virtual extinction of pig industry in sight.

1967 Island Technical Committee to review progress and invite thorough economic investigation of progress of agricultural development in its existing stage; review of 'export' crops in light of needs of mainland Chile and world markets. If favourable report, continue same programme through 1968.

3rd. Phase - 1968-72: Emergence of Island as self-sufficient economic unit

1968 Island economy now dependent upon livestock products (wool and meat) from three intensive grass farming areas, plus 'exportable' produce from islander's allotments. The annual development

to expenditure for agriculture will probably exceed returns until

1972 since the soils will be slow to recover from their long

historical decline and will need regular treatment with ferti-

1972 lizers to accelerate their build-up. Possible development of

poultry products and fish (tuna) canning industries.

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APPENDIX

DESCRIPTIONS OF EASTER ISLAND SOIL PROFILES

PROFILE No. 1 : VAITEA silt loam

Location of profile : 1 1/4 miles North of Vaitea homestead

Relief and altitude : Level area in sloping plain with broad steps formed by lava flows; 990 ft above sea-level.

Parent material of soil : Andesitic lava with some admixture of volcanic dust.

Natural plant cover : Probably Sophora scrub

Actual plant cover : Sporobolus grassland

Soil profile :

0-12" dark brown (7.5 YR 3/2-4/2, moist) slightly stony silt loam; friable but matted with grass roots; strongly developed very fine angular blocky to coarse granular structure; very slightly sticky and slightly to moderately plastic when moist; boundary diffuse; (pH 5.0).

12-24" dark brown to dark yellowish brown (7.5YR 3/2-10YR 3/4, moist) stony silty clay loam, friable; very strongly developed fine and very angular blocky structure; very slightly sticky and moderately plastic when moist; boundary merging; very fine fragments of carbon at 15"; (pH 5.2)

24-27" mainly strong brown (7.5 YR 5/6, moist) light clay with fragments of pale grey and red decomposing porous lava; firm; weakly developed blocky structure; moderately sticky and strongly plastic when moist; boundary irregular; (pH 5.4),

on... grey, reddish and strong brown decomposing lava

PROFILE No. 2 : RANO KAO heavy fine sandy loam

Location of profile : 1/2 mile South of Mataveri, on lower slopes of Rano Kao volcano

Relief and altitude : Moderate planeze slope of about 7°; smooth to slightly rumpled microrelief; 140 ft above sealevel

Parent material of soil : Mainly andesitic scoria, probably overlain with 10" of volcanic dust.

Natural plant cover : Probably grassland

Actual plant cover : Sporobolus grassland

Soil profile :

0-10" brown to reddish brown (7.5 YR - 5 YR 3/3, moist) heavy fine sandy loam; firm to friable and strongly laced with grass roots; moderately developed medium subangular blocky structure breaking to fine angular blocks and coarse granules; very slightly sticky and moderately plastic when moist; boundary merging; (pH 5.9).

10-28" reddish brown (5 YR 3/4-4/4, moist) clay loam, friable to very friable; massive breaking to very fine granules and crumbs; slight to moderately sticky, moderately to strongly plastic when moist; boundary distinct; (pH 5.8),

18-50" red (2.5 YR 4/4, moist) silty clay; firm; weakly developed coarse blocky structure breaking to medium-sized angular blocks and some coarse granuels; slightly sticky, moderate to strongly plastic when moist; boundary merging; (pH 5.8)

on... similar material but lumps of yellowish-red weathered scoria becoming abundant.

PROFILE No. 3 : KAMINA silty clay

Location of profile : 1 mile NNE of Hangaroa township

Relief and altitude : strongly rolling to rolling foothill slopes (12°) of small scoria cone; altitude 300 ft. above sealevel.

Parent material of soil : mainly andesitic scoria and tuff beds

Natural plant cover : probably grassland

Actual plant cover : Sporobolus pasture

Soil profile :

0-8" dusky red (10 R 3/2, moist) silty clay; firm; strongly developed coarse granular structure breaking with difficulty to very fine granules and some crumbs; slightly sticky, moderately plastic when moist; boundary diffuse; (pH 5.9).

8-24" weak red (10 R 4/4, moist) heavy clay; very firm; strongly developed coarse angular blocky structure breaking to medium blocks, coarse and fine granules; slight-to-moderately sticky, very strongly plastic when moist; boundary merging; (pH 5.8).

24-55" somewhat varicoloured, mainly weak red and red (10 YR 4/4 and 10 YR 4/8, moist) silty clay with occasional small fragments of decomposing scoria, firm; weakly developed very coarse blocky to irregular prismatic structure breaking to strongly developed coarse granular structure; slightly sticky, strongly plastic when moist; boundary merging (pH 5.7).

on... similar material with large lumps of weathering scoria.

PROFILE No. 4 : POIKE silty clay loam

Location of profile : About 1/4 mile west of summit of Maunga Poike

Relief and altitude : Small flattish area on long, gentle (5°) planeze slope of Poike volcanic centre; altitude 550 ft above sealevel.

Parent material of soil : Mainly andesitic tuff

Natural plant cover : Almost certainly grassland

Actual plant cover : Sporobolus pasture

Soil profile :

0-15" dark brown (7.5 YR 3/2, moist) silty clay loam; firm-to-friable; strongly developed very fine sub-angular blocky and coarse granular structure; non-sticky and moderately plastic when moist; boundary merging; (pH 5.1)

15-30" brown (7.5 YR 4/4, moist) silty clay; friable weakly developed medium and fine angular blocky structure; moderately sticky and moderately plastic when moist;boundary merging; (ph 5.0)

30-55" reddish brown (5 YR 4/4, moist) silty clay; friable but compact 'in situ'; strongly developed fine and very fine angular blocky structure; slight-to-moderately sticky, moderate-to-strongly plastic when moist; boundary diffuse; (pH 4.9).

55-70" yellowish-red (5 YR 4/8, moist) silty clay; firm-to-friable; weakly developed medium, fine and very fine blocky structure; slightly sticky, moderately plastic when moist; boundary merging (pH 4.8).

on... similar yellowish-red merging to strong brown silty clay with small lumps of soft weathered tuff.

PROFILE No. 5 : VINAPU very fine sandy loam

Location of profile : about 1 1/2 miles southeast of Mataveri

Relief and altitude : about half way up a long planeze (7°) slope of Rano Kao volcano, on broad flattish ledge; altitude 930 ft. above sealevel.

Parent material of soil : probably mainly volcanic dust overlying andesitic tuff and scoria.

Natural plant cover : possibly Sophora scrub

Actual plant cover : eucalyptus plantation.

Soil profile :

0-12" dark brown to brown (7.5 YR 3/2-3/4, moist) very fine sandy loam; friable; no well defined structure in mass but breaking to weakly developed fine blocks granules and crumbs; non-sticky and very slightly plastic when moist; boundary diffuse; (pH 5.4),

12-30" dark brown to dark reddish brown (7.5 YR 3/2-5 YR 3/4, moist) fine sandy clay loam; very friable; no well defined structure in mass but crumbles readily to weakly developed mixture of fine granules and crumbs; non steady, slight to moderately plastic when moist; boundary diffuse; occasional carbon fragments at 20"; (pH 5.6),

30-60" reddish brown (5 YR 4/4, moist) clay loam; very friable to friable; no well defined structure in mass but breaks to fine granules and crumbs; slightly sticky, moderately plastic when moist; boundary alomost distinct; (pH 5.7).

on... reddish brown (5 YR 4/4, moist) silty clay; firm; weakly developed coarse blocky structure; sticky and plastic when moist, boundary not seen; (pH 5.8).

Profile No. 6 : VAI-ARENA silty clay

Location of profile : 1.5 miles NE of Leprosarium.

Relief and altitude : gently sloping plain (about 3^{o}) with smooth to very gently undulating surface; altitude 320 ft above sealevel.

Parent material of soil : porous andesitic lava

Natural plant cover : almost certainly Sophora woodland

Actual plant cover : fallow ground after maize crop

Soil profile :

0-10" dark brown to reddish-brown (75-5 YR 3/2, moist) slightly stony clay firm-to-friable; very strongly developed fine subangular blocky structure; very slightly sticky, moderately plastic when moist; boundary merging; (ph.5.8),

10-20" dark brown to reddish brown (5 YR 7.5 YR 3/2, moist) stony fine sandy clay loam; friable to very friable; no clear structure in mass but breaks to fine blocks, granules and crumbs; slightly sticky, slight-to-moderately plastic when moist; boundary diffuse; small fragment of carbon at 18" (pH 6.3)

20-40" dark reddish brown (5 YR 3/2, moist) stony clay loam (or heavy fine muddy clay loam); friable-to-firm; no distinct structure in the mass but breaks to granules and crumbs; slightly sticky, moderately plastic when moist; boundary diffuse; (pH 6.7),

on... dark reddish brown (5 YR 3/2, moist) very stony clay loam grading to silty clay at about 60"; firm; weakly developed medium angular blocky structure; moderately sticky and plastic when moist; boundary not seen; (ph 7.0)

PROFILE No. 7 : ONE-MEA steepland soil, fine sandy loam

Location of profile : Northern side of Maunga Ruhi

Relief and altitude : steep slope (36°) of Ruhi scoria cone, near centre of island; altitude 890' above sealevel

Parent material of soil : andesitic scoria and tuff with some colluvial drift containing volcanic dust

Natural plant cover : possibly Sophora scrub

Actual plant cover : Sporobolus grassland

Soil profile :

0-5" dark reddish brown (5 YR 3/2, moist) fine sandy loam; friable; strongly developed very fine blocky and granular structure; non-sticky and very slightly plastic when moist; boundary distinct; (pH 5.2)

5-9" dark reddish brown to reddish brown (5 YR 3/3-4/3, moist) heavy silt loam; friable; strongly developed very fine granular and crumbs structure; slightly sticky, moderately plastic when moist, boundary distinct; (pH 5.4)

9-16" dark reddish gray (5 YR 4/2, moist) clay; firm; strongly developed coarse angular blocky structure breaking to medium and fine sub-angular, slightly flattened blocks (laminar fracturing); moderately sticky, very strongly plastic when moist; boundary diffuse; (pH5.6).

16-32" varicoloured; mainly yellowish red (5 YR 3/1) and dark red (10R 3/6) heavy clay containing up to 4" blocks of weathering scoria and tuff; very firm, compact 'in situ'; very weakly developed very coarse blocky structure; slight-to-moderately sticky, moderate-to-strongly plastic when moist; boundary merging; occasional fire carbon fragment at 17"-20"; (pH 5.7).

on... multicoloured weathering tuff.

PROFILE No. 8 : ORITO fine sandy clay loam

Location of profile : below summit to Maunga Orito, and northern side

Relief and altitude : rounded summit with about 10° average slope, slumped and sheet eroded; corrugated micro-relief; altitude, 675 ft above sealevel

Parent materials of soil : pale-coloured andesitic tuff

Natural plant cover: probably grassland

Actual plant cover : Sporobolus grassland

Soil profile :

0-7" reddish gray (5 YR 5/2, moist) fine sandy clay loam; firm-to-friable; very strongly developed very fine subangular blocky structure breaking to granules and crumbs, very slightly sticky, moderately plastic when moist; boundary distinct, (pH 6.1)

7-18" brown (7.5 YR 4/4, moist) slightly mottled strong brown (7.5 YR 5/6), clay; friable-to-firm; weakly developed coarse blocky structure breaking to fine granules; non-sticky and slightly plastic when moist; boundary distinct; (ph 5.7),

18-22" gray (10 YR 6/1, moist) weathering tuff, soft and with general texture of sandy clay; firm; very faint blocky fractures; slightly sticky and plastic when moist; boundary merging; (pH 5.3)

on... pale grey, pale yellowish brown, etc. weathering volcanic tuff

PROFILE No. 9 : TEREVAKI silty clay

Location of profile : 1/4 mile south of lip of Rano Aroi crater lake

Relief and altitude : flat somewhat swampy plain with slightly irregular (hummocky) micro-relief; altitude 1180 ft above sealevel

Parent material of soil : Andesitic tuff

Natural plant cover : probably Sophora woodland

Actual plant cover : induced pasture with a high proportion of Sporobolus and small sedges.

Soil profile :

0-8" dark grey (10 YR 3/1, moist) silty clay; firm; moderately developed medium and fine blocky structure; non-sticky, slightly plastic when moist; many worms; boundary sharp,

8-10" strong brown (7.5 YR 5/8, moist) mottled dark grey, silty clay; firm-to-friable; strongly developed fine blocky structure; slightly sticky and moderately plastic when moist; boundary merging,

10-16" yellowish red (5 YR 4/8, moist) silty clay; friable; moderately developed medium and fine blocky structure breaking to small, crisp granules; moderately sticky and plastic when moist; boundary diffuse; moderate sized carbon fragment at 12"-16" depth.

16-30" varicoloured mainly reddish grey (10R 5/1, moist) mottled and flecked grey (10 YR 6/0) very pale, brown, and bluish grey, fine sandy clay with weathering tuff; friable-to-firm; no visible structure in the mass but breaks into fine blocks and irregular granules; slightly sticky and strongly plastic when moist; boundary merging.

on... fairly hard volcanic tuff

PROFILE NO. 10 : RANO AROI fibrous peat

Location of profile : Rano Aroi crater lake

Relief and altitude : Flat reed swamp floating on surface of crater lake; altitude 1200'

Parent material of soil : organic residues

Natural and actual plant cover : "Totora" reeds, Polygonum water weed and Campylopsis moss

Soil profile :

0-8" very dark grey (5 YR 2/1, moist) fibrous peat with dense mass of living and dead 'totora' leaf and stem bases.

8-60" reddish black (5 YR 2/2, moist) fibrous loamy peat with a high proportion of living roots

60-80" pale brown peaty/ loam mingled with very thick mat of living roots.

on... water

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ACSW/pr.,gv.,cm.
23.4.62