

農林部中央農業實驗所

特刊 第二十七號 * Special Publication No. 27 * 民國卅一年六月 * June, 1942

四川之土壤與農業

利 查 遜

SOILS AND AGRICULTURE OF SZECHWAN

By

H. L. Richardson.

PUBLISHED BY
THE NATIONAL AGRICULTURAL RESEARCH BUREAU
MINISTRY OF AGRICULTURE AND FORESTRY
CHUNGKING, CHINA

農林部中央農業實驗所印行
所址 四川榮昌

農林部中央農業實驗所

特刊 第二十七號 * Spécial Publication No. 27 * 民國卅一年六月 * June, 1941

四川之土壤與農業

利查遜

SOILS AND AGRICULTURE OF SZECHWAN

By

H. L. Richardson

PUBLISHED BY

THE NATIONAL AGRICULTURAL RESEARCH BUREAU
MINISTRY OF AGRICULTURE AND FORESTRY
CHUNGKING, CHINA

農林部中央農業實驗所印行
所址 四川榮昌

WEIGHTS AND MEASURES: CONVERSION TABLE.

(The old, local, weights and measures differed widely in different parts of China. The new, national standard units, which are the ones given below, are now generally adopted; they are based on the Metric System. They are sometimes distinguished from the old units by the prefix *shih*: e.g., *shih catties*.)

1 catty	= 500 g. = 1.1 lb.
100 catties	= 1 picul = 50 kg. = 1 cwt. (English).
2000 catties	= 1 ton (metric or English).
1 foot (Chinese)	= 33.3 cm. = 1.1 ft. (English).
1 mou	= 6000 sq. ft. (Chinese) = 667 sq. m. = 797 sq. yds. = 1/15 ha. = 1/6 acre.
1 catty/mou	= 7.5 kg./ha. = 6.7 lb./acre.
100 catties/mou	= 7.5 dz. or q./ha. = 6 cwt/acre = 12 bushels/acre. (approx.)

CORRECTIONS.

(Excluding minor misprints, for the number of which, due to war conditions, the author offers his apologies.)

Page Line	As printed	Corrected
1 4	(see Bibliography, p.)	(see Bibliography, p.123)
7 10 from bottom	September, 0.44;	September, 0.32; October, 0.44;
8 24	Coching Chu (Aa); see also	Coching Chau (4a); see also (p, 124)
23 16	of deposition of down-	of deposition or of down-
28 last line	major headings (underlined)	major headings (in italics)
30 22	.29: thus	2.0; thus
40 7	prodocal soils	pedocal soils
42 12	Singkiawen Top soil 7.0	Singkiawen Top soil 8.0
47 12	of the steppe type	of the mountain meadow or steppe types
50 4 from bottom	(p.18; Fig. 3)	(p. 14; Fig. 3)
52 11	(cf. p. 42)	(cf. p. 34)
52 12 from bottom	near Meihsien	near Pengshanhsien
54 10 from bottom	peanuts, 0.1, soybeans, 0.1.	peanuts, 0.1, peppers, 0.1. soybeans, 0.1,
56 16	to enrich the remains soil.	remains to enrich the soil.
56 17	<i>Oital are</i>	<i>Oats are</i>
58 last line	(<i>Canariut lobamwun</i> ,	(<i>Canarium album</i>), not
62 6 from bottom	(<i>Diosporus kaki</i>)	(<i>Diospyros lotus</i>)
68 2 from bottom	medium-large, 13.7;	medium, 13.6; medium-large, 13.7;
77 19	(p. 19)	(p. 14)
78 2	(pp. 41-42)	(p. 34)
80 13 from bottom	(p. 70)	(p. 63)
82 21	(p. 25)	(pp. 18-19)
93 8	brown rather than earth on	brown earths rather than on
94 15 from bottom	(p. 37)	(pp. 24, 30)
96 18	(p. 80)	(p. 72)
96 8 from bottom	(p. 37)	(p. 30)
97 24	(pp. 40-41)	(pp. 33-34)
123 Reference (9)	<i>Geol., China, 1933, 13 Soc.</i>	<i>Geol. Soc. China, 1933, 13,</i>
124 Reference (17)	<i>Socl. China, 1927, 6, 9 - 3.</i>	<i>Soc. China, 1933, 6, 9 - 36.</i>
125 4	Nanking Astronomy	Nanking Agronomy
125 12	more than heli	more than half
125 5 from bottom	the most condition	the moist condition
127 15	alluvial soils and pH 8.1,	alluvial soil had pH 8.1,
127 9 from bottom	the Socials of China",	the Soils of China",
145 1	superphosphate, and boen	superphosphate, and bone

SOILS AND AGRICULTURE OF SICHUAN

PREFACE.

This publication was first prepared as a Report for the Directors of the National Agricultural Research Bureau, when under the Ministry of Economic Affairs. It was found to be of some general interest, and the Directors recommended that it should be printed as a Special Publication of the Bureau, but the writer realises that it bears the defects of having been written in Report form. Some of the material can only be of local interest, while the Appendices would better have been incorporated in the main part of the text before publication. To make any extensive revision, however, would practically involve rewriting the Report, which cannot be undertaken because of the pressure of later duties. Accordingly, the publication is presented in its original form with the minimum of alteration. It refers in the first place to the year 1938, during which the journeys mentioned in the text were made, and the crop survey data (summer crops) are those of that year. Later data, when available, do not present a very different picture from that described; the chief difference would lie in an extension of the area of crops of importance to the interior economy of western China under war conditions: namely, cotton, sugar-cane, and rape-seed, as well as less important crops such as indigo. Vigorous extension work by Provincial and National authorities has led to great increases in the production of these crops, and also of silk, tea, tung-oil, and power alcohol. The latter, derived from molasses, has largely replaced petrol for the motor traffic of the Province; rape-seed oil is also used as a propellant, either directly in Diesel engines or, after "cracking", to produce petrol for motor cars and trucks.

- (1) Chengtu - Kweichow - Kweichow - Chengtu (by bus).
- (2) Chengtu - Kweichow - Kweichow - Panlong Shan (4,000 ft.), returning by a different route to Kweichow. (By car and on foot.)
- (3) Chengtu - Kweichow and return by truck.
- (4) Chengtu - Kweichow - visiting the Sugar Cane Research Station - Tachung - Panlong Shan and return by car, car, and bicycle.
- (5) Chengtu - Kweichow - Cotton Sub-station - Sugarcane Research Station - Nanchang - Kweichow Station - Sichuan Agriculture Sub-station - and return by car and foot.
- (6) Chengtu - Kweichow and return by plane.
- (7) Chungking - Wanchow - Wanchow (to Ichang in Hubei) and return by steamer.
- (8) Chungking - Chengtu (by bus).
- (9) Chengtu - Kweichow (by bus) - Omelshan (4,000 ft.) - Omel Shan (3,000 ft.)

四川之土壤與農業

摘 要

本書之內容主要材料係根據作者在一九三八年歷次旅行四川省各地所得記錄，並旁及各種有關文獻編著而成，詳細內容包括圖表及地圖等請參閱全書，本書之首有各章目錄表，以便讀者查閱，茲將本書大綱，譯成中文摘要敘述如下：

本書首先敘述四川之地理與氣候，該省幅員廣大，長江及其支流穿越其間，四周邊境多崇山峻嶺。中間部份地勢較低，但仍多邱陵起伏，由北向南逐漸傾斜。岩石多呈紫紅色故有赤色盆地之稱，全境氣候植物及土壤之分佈隨地勢高低而有明顯之變異。

川省氣候溫和，冬無嚴寒夏無酷暑，與他省不同，冬季比較涼燥，夏季比較溫濕，屬於“溫溫帶”之氣候，此種潤溼溫和氣候之形成，大概由於四境多高山之環繞，與陰晴多雲之天氣所致，冬季甚少霜雪，乾燥亦不甚嚴重，故冬作極少受乾旱凍害之災，惟有時常遇春旱，致影響水稻移植，因此稻田極有蓄水與灌溉之需要“赤色盆地”中全年雨量約為一〇〇〇公厘，對於水稻生長不算太多，雨量分佈由東南向西北逐漸減低直至高山邊境。每月雨量之分佈情形，實際最為重要，在本書中對此曾有詳細討論。

該省地質歷史頗為複雜，但對於地理狀況土壤情形關係極大，赤色盆地中土壤至為肥沃，蓋其土壤之母岩為在極度乾燥氣候下沉積而成之紫色岩石，該岩石沉積於地面河床或湖泊上未曾受到劇烈的洗滌作用，故本身頗富植物養分與一般水成岩迥然不同，其次因為該岩石形成之地質年代不遠（多在白堊紀時代）沉積物所受壓力不甚嚴重，所受褶皺亦不甚烈，其形成之岩石多為鬆軟之粘頁岩與砂岩，極易風化，因此表土雖受沖蝕，而新土亦易產生，全境土壤多為白堊紀岩石風化而成，在高山山頂，則有更古老之岩石，在河流兩旁及沖積平原上則有屬於第四紀或近生代幼年之沉積物，在本書中對此有詳細記述，並論及岩石之形成，受氣候變化及冰川影響之關係。

四川主要土類為沖積土，紫棕壤或紫棕土，黃壤，棕壤，高山草地及西北角之栗鈣土與發育不完全之黑鈣土，作者曾將此種主要土類再依魯賓生氏之土式 Suite 法分類，即以相同或相似之母岩所形成之土壤，歸為一類，如此分類對於土壤調查概測，極為方便有此根據對於土地之利用，亦易作廣泛之討論，在本書中對於各種土式之土壤肥沃度及利用狀況詳加敘述。

盆地中作物之栽培及土地之利用，極為精細複雜，主要夏季作物及冬季作物栽培面積及其分佈區域，在本書中有表可查。水稻為主要作物，其次為小麥，甘藷，玉蜀黍，

大麥及油菜，冬季及夏季豆科作物亦頗重要，均與其他作物混作，棉花，烟草，甘蔗所佔之面積雖小，但在經濟價值上頗有地位，其他作物，果樹及各種經濟樹木，如桑，茶，油桐，漆樹等在本書中均有記述，木材及薪柴出產頗多，在西北角上有廣大之放牧草地，但在盆地中則甚少見。

水稻區域施肥之方式實為中國農民傳統之特色，施用肥料完全利用當地材料，如人糞尿及豆科綠肥等，農家肥料雖已盡量利用，但數量仍不夠，農田仍感肥料不足，土壤與作物均顯示養分缺乏，如果肥料來源一旦解決，當可大量增加生產，此項問題解決辦法當從綠肥骨粉之利用，及人造肥料之輸入或製造上着手，四川土壤氮素養分最感缺乏，其次為磷素，磷素肥料對於黃壤及成都粘土最感需要，根據四川省土壤及作物情形，作者對於本地肥料及人造肥料最適當之施用有所指示。

四川土壤沖蝕甚感嚴重，對於地力之保持與消失，影響甚大，若非盆地中紫紅色岩石風化極易，養分又多，則如此嚴重之沖蝕誠不堪設想，幸而有養分相當豐富並有繼續不斷風化之物質，以代替沖蝕消失之土壤，此種土壤沖蝕以片狀沖蝕多於溝狀沖蝕，因此不易引起一般人之注意，然而每年夏季長江中所含泥砂數量之多即可知土壤沖蝕之如何程度，所沖蝕之泥沙均為盆地中或高山之肥沃表土，影響沖蝕之因子及水土保持方法，在本書中曾加論述，並指出該省農民，亦已應用良好土壤保持方法；此種良法值得推行改進，作者提出兩種於邱陵地上極有成功希望之土壤沖蝕防治方法，第一築成梯田或梯地，第二凡栽甘蔗甘薯玉蜀黍之地應改成順等高溝畦耕作，該省土壤沖蝕調查極感需要，作者對於該項調查分類根據有所建議。

畜牧在四川亦甚重要，但一般農家飼養家畜數量不多，故此問題往往易致忽視，然而以全省農家所養家畜估計之，其數量當甚可觀，四川之西北部有廣大牧地，該區畜牧事業重於農業，其居民多為牧者，畜牧之改進與發展更應舉辦，作者對此亦曾作各種建議。

作者在考察四川省土壤與農業時在旅途中曾參觀四川省農業改進所各試驗場所，對於各試驗場所之互相連繫及推廣工作殊可稱佩，作者自各地土壤立場上亦間或對各試驗場所作種種建議。

在最後一章作者對於各種意見與建議再作總括敘述，意見與建議之範圍包括一般農業情況，土壤肥力及其保持，施肥方法，各種農作物之生產，農產品之輸出，土地改良及移民開墾計劃，以及指導與推廣工作等。

書末有附錄四件：附錄一，對於內江甘蔗試驗場之建議，在附錄中詳細敘述該場試驗地之土壤，田間試驗及將來研究計劃，附錄二，四川省及其他西南各省田間肥料試驗計劃，并附帶敘述採取土壤樣本方法，附錄三，冬水田問題之討論，敘述冬季蓄水對於土壤肥力之影響，又論及改變一部份冬水田為多作田之可能性，附錄四，建議在灌縣及彭縣河流域舉辦水土保持及利用之調查與試驗工作。

CONTENTS.

	Page.
INTRODUCTION; ITINERARY	1
GEOGRAPHICAL SKETCH	2
CLIMATE	4
GEOLOGY	15
SOILS	26
CROPPING AND LAND UTILISATION	45
MANURING AND THE USE OF FERTILISERS	66
SOIL EROSION: SOIL AND WATER CONSERVATION	76
ANIMAL HUSBANDRY	87
AGRICULTURAL RESEARCH STATIONS	92
SUGGESTIONS AND RECOMMENDATIONS	103
BIBLIOGRAPHY	123
APPENDICES:	
I. PROVINCIAL SUGAR CANE RESEARCH STATION, NEIKIANG	125
II. FIELD EXPERIMENTS ON SOIL FERTILITY AND MANURING	132
III. WINTER WATER LAND	146
IV. SOIL AND WATER CONSERVATION, WATERSHED PROJECTS	150

SOILS AND AGRICULTURE OF SZECHWAN

This publication is based on journeys made by the writer in the Province of Szechwan during the months of February to December, 1938. The writer's own observations and notes have been supplemented by a study of the available literature (see Bibliography, p.), and of climatic and other data published by the Provincial Bureau of Reconstruction; his endeavour has been to give as complete a picture as possible, in limited space, of the agriculture and of the factors, especially climate, geology, and soil, which control it.

There are two questions to be answered in such a study: "what?" and "why?". "What?" is a matter of observation and statistics: it reports on the past; it is a poor guide to the future, unless one has at least an idea of "why?". The writer's aim has constantly been to infer explanations or reasons for the phenomena studied. With the limited data so far available, his conclusions can only be tentative, but he trusts that if they have to be corrected it will only be in matters of detail. For this reason considerable space has been given to the discussion of climate and geology, because of their very direct bearing on present agricultural conditions and future developments. For example, the facts that some hundreds of millions of years ago certain deposits were laid down under the sea during wet climatic conditions, while other materials were deposited in an inland basin when the climate was hot and dry, are directly responsible for the extreme poverty of some farms in the Province, and the high fertility, varied productivity, and relative prosperity of others.

ITINERARY

The following journeys have been made within the Province (on either official or private business):

- (1) Shensi border - Kuangyuan - Mienyang - Chengtu (by bus):
- (2) Chengtu - Kuanhsien - Shuimoko - Panlung Shan (4,000 m.), returning by a different route to Kuanhsien. (By car and on foot.)
- (3) Chengtu - Sumatou and return (by truck).
- (4) Chengtu - Neiking (visiting the Sugar Cane Research Station) - Tzeliutsing - Peimuchen and return (by bus, car, and ricksha).
- (5) Chengtu - Kienyang (Cotton Sub-station) - Suining (Cotton Research Station) - Nanchung (Sericulture Station) - Sichung (Sericulture Sub-station) and return (by car and truck).
- (6) Chengtu - Chungking and return (by plane).
- (7) Chungking - Wanhsien - Wushan (to Ichang in Hupeh) and return (by steamer).
- (8) Chungking - Chengtu (by bus).
- (9) Chengtu - Kiakiang (by bus) - Omeih sien (ricksha) - Omei Shan (3,000

m.), and return (on foot) - Kiating (by litter) (visiting the Forestry Sub-station near Omeih sien and the Sericulture Sub-station at Kiating). Kiating - Chungking (steamer).

(10) Chungking - Peipeh (West China Scientific Institute) (by car) - Hochuan (by steamer) (Provincial Agricultural Sub-station) - Tungliang - Pishan - Chungking (by litter and car).

(11) Chungking - Kiangtsing (Horticultural station) - Luhsien (Provincial Agricultural Sub-station) (by steamer).

(12) Luhsien - Shihtungchen, and return by a different route (by litter and boat).

(13) Luhsien - Ipin - Kiating (by plane) - Chengtu (by bus).

(14) Chengtu - Penghsien - Pailuting - Tientai (2,500 m.) and return (by litter and on foot).

(15) Chengtu - Kuanhsien (visiting the Forestry station) (by bus) and return (by ricksha).

The country around each of the following cities has been studied in several directions, usually travelling on foot: Kuangyuan, Chengtu, Neikiang, Tzeliutsing, Suining, Nanchung, Sichung, Chungking, Hochuan, Kiangtsing, Luhsien, Kiating, Kuanhsien.

Detailed notes were kept of all journeys and visits.

GEOGRAPHICAL SKETCH

The Province of Szechwan is roughly triangular, with its base on the Tibetan Plateau and its apex in the east, where the Yangtze Kiang has cut through the Tapa-shan range to form its famous gorges. The sides of the triangle, to the north and south of the Province, are also mountain ranges. Thus the Province as a whole is lower in the middle than at the edges, and since the hollow land in the centre consists of purplish-red rocks geographers have named this the Red Basin of Szechwan. Actually, the "basin" is so wide and its floor so uneven, as a result of geological dissection, that it does not appear at all basinlike to one who travels across it. This region is largely one of arable cultivation. The mountains around the Basin are mostly of moderate height (1,500 to 3,000 metres), but along the western and north-western edge are some extremely high peaks and ranges, unexplored and unsurveyed, whose altitude appears to be from 5,000 to 7,000 metres. These ranges are so high that they cause the deposition of most of the moisture carried by rainbearing winds from the east, so that beyond them to the west the country is much drier than to the east. For this reason they have been called the "rain-screen mountains." Among the mountains, cultivation is usual at lower levels; scrub and forest at higher altitudes.

In the far north-west of the Province is a considerable area 3,000 m. or more

in altitude, around the headwaters of the Yangtze and Yellow River tributaries, which is almost unexplored. It is reported, however, to consist largely of grassland, similar to the high plateau grasslands that extend all the way across northern Tibet and Chinghai.

Another considerable area to the south-west, in the big bend of the Yangtze Kiang, was until recently part of the Province of Szechwan, but now it is included in Sikang. This region includes Yachow, which is really on the border of the Red Basin, and a highly dissected tangle of mountains and valleys of which Sichang is the centre. In discussing the soils and climate of the Province it will be convenient to include this area with Szechwan.

The east of the Province, east of Hochuan and the Hou Kiver, does not appear so elevated on the map as the land around the border, but it is a region of high and complex relief. There are many more-or-less parallel anticlinal ridges, running approximately from south-west to north-east; each ridge is steep and mountainous, exposing older rocks, and soils that soon become infertile from erosion if cultivated; between the ridges lie rather level hollows on purple-red rocks, similar to the land of the Red Basin. The geological map (9), and Wilson's account (16), both suggest that mountainous uplands form a considerable proportion of the area of this region, which therefore differs considerably from the Red Basin.

An interesting feature of the Province is the well-marked "vertical zonation", of climate, vegetation, and soils, which may be observed between low and high altitudes. Wilson gives a very clear description of the climatic and vegetation zones; briefly, they are as follows:—

(1) *Warm temperate zone* (below 2,000 ft., 600 m.): the "belt of cultivation," with bamboos, palms, cypress, pine, tung oil, oranges, vegetable tallow, insect white wax, as typical trees; rice, cotton, sugar cane, maize, tobacco, sweet potatoes and legumes as summer crops; and wheat, rape seed, cabbage, Irish potatoes, legumes, and hemp as winter crops.

(2) *Temperate zone* (2,000-5,000 ft., 600-1,500 m.): the "evergreen rain forest" belt, with evergreen oaks, *Castanopsis*, *Lauraceae*, holly, pines, *Cunninghamia*, and ferns. Cultivation is still common, the chief crops being similar to the previous zone, but maize displaces rice as chief food crop and winter crops are less important. The upper limit of rice cultivation is around 4,000 ft. (1,200 m.). Tea is grown.

(3) *Cool temperate zone*, (5,000 to 10,000 ft; 1,500 to 3,000 m.): chiefly deciduous, flowering trees and shrubs, of genera familiar in North America and Europe; also rhododendrons, conifers, tall herbs and flowering plants. The chief crops are wheat, maize, and Irish potato, the upper limit of maize cultivation being about 8,500 ft. (2,500 m.). Walnut and varnish trees are common. Towards the upper limit of the zone, forests of conifers are found.

(4) *Sub-alpine zone* (10,000 to 11,500 ft; 3,000 to 3,500 m.): A narrow transition belt, mostly moorland, with dwarf bamboo and scrubby shrubs (especially rhododendrons); some large coniferous forests (larch, spruce, and silver fir).

Wheat and barley are the crops grown. (Note by writer: also Irish potatoes.)

(5) *Alpine zone* (11,500 to 16,000 ft; 3,500 to 4,800 m.) The limit of tree growth, and also of wheat and barley, is around 12,000 ft. (3,600 m.); of woody scrub, around 15,500 ft. (4,600 m.); so that this zone is mostly occupied by herbs, many with intensely coloured flowers, and by grasses. Meadows, heaths and moorlands occur. Rhubarb and other medicines are grown.

(6) *High alpine zone* (16,000 to 17,500 ft; 4,800 to 5,200 m.). Glaciers and moraines and alpine deserts occur; the limit of vegetation is around 16,500 ft. (5,000 m.), cushion plants and herbs being the highest plants.

(7) *Perpetual snow* (above 17,500 ft. or 5,200 m.; Minya Konka, in Sikang, is 24,900 ft., or 7,600 m.). The high level of the snow-line is attributed to the dryness of the climate at these altitudes.

The whole Province of Szechwan is drained by the Yangtze Kiang (which rises in Sikang and Chinghai, and later flows in a north-easterly direction not far from the south-eastern border of Szechwan), and by the tributaries of this River. The chief of these are the Min Kiang (with its big tributary, the Tung Ho), the T'o Kiang or Lu Ho, the Kialing Kiang (with several large tributaries), and the Wu Kiang, which flows for most of its course in Kweichow. These rivers are important for transport, especially within the Red Basin. The rich, muddy colour of their flood waters, in the rainy season, supplies silent evidence of the amount of fine, fertile soil which is eroded and lost from the Province each year.

Until lately, transport conditions were extremely primitive; in the last few years, under more stable and progressive governments, road, steamer and air services have been opened up within the Province, but there is still a great deal to do. Outside the rivers and motor roads, carrying is done almost entirely by man power, animal and cart transport being practically unknown. These conditions intensify many agricultural problems.

The Province is rich in minerals, especially coal, which is mined by native methods. It is famous also for its salt deposits, which are worked as brines. Other minerals are mined only on a small scale: their development, and some degree of industrialisation, might do a good deal to ease the pressure of population on the land and raise the general standard of living.

The dimensions of the Province are some 800 km. from east to west and rather less from north to south. Its human population is estimated at from 50 to 70 millions, of which about 10% lives in cities, and the remaining 90% is directly or indirectly supported by agriculture. The Province is thus similar to Germany (without Austria) in size and population, but it shows a vast difference in the proportion of people on the land, and in the average wealth or, rather poverty, of the inhabitants.

CLIMATE

Climate is everywhere the most important factor controlling land utilisation, and in this respect Szechwan is both favoured and remarkable. The average

rainfall, which for the Red Basin is around 1,000 m.m., is fairly well distributed, and it is sufficient in normal seasons for all crops. In view of its position in the interior of a continent, and in comparison with, say, Nanking (which is on about the same latitude as Chengtu), Szechwan has an unusually mild climate. Severe frosts are almost unknown in the Basin, while the summers, though warm and moist, are cooler than those down-river. Indeed, the Province, encircled by its mountains, has been said to make its own climate: and although it is not uninfluenced by the large-scale air movements that make up the climate of Asia, even these are considerably modified. To come to Szechwan in the winter time from the adjoining province of Shensi is to experience a dramatic contrast between the frozen, yellowish land of the Wei Valley and the lush green growth of the Red Basin.

In order to understand the climate of Szechwan, it is necessary first of all to consider the large-scale air movements referred to above. These depend on the well-known fact that, water having a higher specific heat than land, a large land surface becomes hotter in summer and colder in winter than adjoining sheets of water. Consequently:

(1) In winter, the intense cold of Central Asia causes a permanent area of high barometric pressure (an anticyclone) over Siberia, the Gobi Desert, and Tibet from which cold, dry air flows out over the surrounding countries. This is the "winter monsoon": in Northern China it is associated with clear skies and frosty weather, with occasional freezing north-west winds and dust storms; these cold storms sometimes reach to Nanking, Shanghai, and even Hongkong.

(2) In summer, the converse condition, the heating up of Central Asia, causes more or less permanent low pressure areas in North China, Turkestan, and Tibet; and warm, moist air is drawn in from the coasts,—from the China Sea and the Bay of Bengal. This is the "summer monsoon", but it is less strongly developed in China than is the Monsoon of India. The moist air from the sea is the original source of the summer rains, but as will be seen, especial circumstances are necessary to cause the condensation and precipitation of the moisture as rain.

The essential factor in the production of rain from moist air is an upward movement of the air, which cools it, reduces the amount of water it can hold as vapour, and so leads to the formation of mist, cloud, and rain. Without such vertical movement, even monsoonal air will not precipitate rain, although it may be moist, and cloudy overhead.

The simplest cause of vertical movement is a range of hills or mountains; the air rises while attempting to cross the range, and if the air is moist, rain or snow is the result. Thus the rainfall on hills and mountains is almost always higher than that on surrounding level country, at least on the side facing moisture-bearing winds.

Vertical movements of air may also be set up by atmospheric causes: for exam-

ple, the convection currents resulting from heating by the sun. Localities which for any reason heat up quicker than those adjoining will give rise to currents of warm, rising air which, if moist, condense into clouds at a certain height (producing the well-known cumulus clouds); and these may later form thunderclouds and give rise to intense rain storms: "convictional rain".

Again, there is a tendency for the cold air flowing out from the poles, or from a continental anticyclone, to advance as a thin layer, a wedge-like "front", which flows underneath the local warm air and forces this upwards. The latter thereupon produces clouds and rain, sometimes in a long line which is known as a "line squall" or "cold front". Such a front sweeps across the country, and, because of the rotation of the earth, its movement soon becomes a circular one: the air over a large area takes on a gentle, whirl-pool like movement, which has been named a "cyclone", or a "depression". (Because the barometric pressure is less towards the centre of the whirl-pool). These depressions usually have a diameter of about a thousand miles, and they move slowly across the continent along fairly regular routes; the air movements, being partly vertical, are associated with rain, and indeed they are one of the chief causes of rain falling in the Lower Yangtze Valley.

The rising air of convection currents may also take up a circular, whirlpool-like motion: on land it then forms violent local storms, often with a dark centre of rising dust and debris, which are called tornadoes; similar but larger storms originating at sea are commonly called typhoons, and they may sweep inland from the coast. These storms are usually accompanied by intense rains.

All of these causes—hills, convection currents, depressions, and typhoons—combine with the moist monsoonal air from the sea to cause the precipitation of rain in China, especially during spring, summer and autumn. It should be borne in mind that the rain which falls in inland places has probably not all come there directly from the sea. It may have fallen as rain nearer the coast, been re-evaporated or transpired and then precipitated again, one or many times on its journey inland. The first rains of spring, for example, may result from the local transpiration and precipitation of water which fell as rain the previous year and even then may have made several stops on its journey from the sea. Rice, and paddy fields, are probably especially important as a local source of rain.

With this account of the mechanisms involved, it is hoped that the explanation of Szechwan's climate will be easier to follow. First will be given a general outline of climatic conditions in the Province; then those aspects which are especially important for the utilisation of land in the different regions will be discussed in more detail.

The *Winter* in Szechwan is fairly dry, but not rainless; as has been said, the winters are much milder than those further to the north, east or west. The out-flow of cold desert air that affects Sian and Nanking seems to be deflected by the double range of mountains which lies to the north of the Province (the Tsinling

Shan and Tapa Shan); instead of the clear skies and frosty nights of the north, the Province usually has dull cloudy skies and cool, but not freezing, winter weather. This type of weather, windless, overcast, cool and humid, but with little rain, is also common in England in the winter, where it tends to occur when a large anticyclone has either centred itself over that country or has extended there from the continent of Europe. Such weather is well named by meteorologists, "anticyclonic gloom." The general experience in Szechwan seems to be that an almost continuous state of anticyclonic gloom persists there during the winter months. This may be attributed in a general way to the influence of the Siberian anticyclone, but it is probably reinforced by local conditions. Possibly a certain amount of the cold air from the mountains encircling the Province drains down into the Basin, and lies there, almost stagnant, for considerable periods. The warmer air which is gently displaced lies on top of the cold air; its moisture condenses into a layer of cloud, which forms a "roof" like that of a greenhouse. This prevents the radiation of heat away from the earth at night, and so preserves the Province from frosts and extremes of cold.

In Eastern China the winter and spring are periods of fairly frequent depressions, some of which are charted as arising in or near Szechwan and travelling eastwards along the Yangtze valley or just south of it. There is not yet sufficient meteorological information for a discussion of just where and how these depressions arise. The writer has observed the occasional passage of "fronts" over Chengtu, from north-easterly or north-westerly directions, but the meteorological phenomena associated with them have been much less pronounced than is usual with fronts in Europe. They may have represented early stages in the air movements that produce depressions. It seems likely, however, that most of the "Yangtze Valley depressions" originate to the east of Szechwan. (Dr. Coching Chu, private communication).

In any event, the frequency of the depressions which pass down the Yangtze valley is not really very high, from the point of view of influencing the day-to-day weather conditions. If the totals quoted by Buck (2) are reduced to numbers per month, the mean number of depressions per month on paths 3 and 4 (Yangtze Valley, and Szechwan) is as follows: January, 1.36; February, 0.96; March, 1.44; April, 1.40; May, 1.12; June, 0.96; July, 0.12; August, 0.20; September, 0.44; November, 0.56; December, 0.72. Total for the year, 9.60. Probably only a small proportion of these have any effect on the weather of western Szechwan (Chengtu region), although the weather of eastern Szechwan (Chungking and further east) may be more under the influence of the depressions, as will be seen later.

In the *Spring*, as the cold interior grows warmer, the Siberian anticyclone breaks up. Its place may be taken for a short while, however, by a smaller anticyclone centred over Tibet. It has been said that as long as this anticyclone persists, winds bringing moisture and rain from the east are unable to have much influence on the Red Basin, and it is not until the break-up of the Tibetan anti-

cyclone, in late Spring, that the rains really begin. If, for any reason, the anticyclonic conditions remain stable, spring droughts may ensue, with failure of crops, especially of rice, and local famine may be the consequence.

As the Tibetan anticyclone breaks up, the influence of the depressions, with associated warmer, moister air drawn in from the sea, and also the influence of convection currents generated by the increasing power of the sun, extend over the Province from the east; these combine to bring the spring rains, which (as will be seen below) arrive latest in the west of the Red Basin.

The explanation given above, in terms of anticyclones and depressions, is probably the simplest way of representing the influence of meteorological conditions on the weather of Szechwan. But its exact interpretation offers some difficulties: the Tibetan Plateau is at such an altitude that weather conditions on the Plateau come into the sphere of the middle and upper atmosphere, rather than the normal lower-atmosphere movements that produce much of our surface weather. Again, the ranges of high mountains lying between Tibet and Szechwan probably shield the latter Province from many of the effects of Tibetan weather, just as the Himalayas shield India. Thus, there is no outrush of cold air from the Tibetan anticyclone into the Red Basin, comparable with the outrushes from the Siberian anticyclone over north China. It does appear, however, that when Tibetan air reaches the Red Basin, after shedding any moisture it may contain while crossing the high mountains, and then undergoing compression as it descends to the lower levels of Szechwan, it will be relatively warm and dry. (The *fohn* effect.) Again, the general circulation in the upper atmosphere over this part of China is from a westerly direction (compare Coching Chu (Aa); see also Burdsall and Emmon's account of their climb of Minya Konka, 7,600 metres, where the ice cornices on the ridges of the mountain leaned towards the east). Now, during Spring and Summer at least, the air over Tibet may be relatively warm, for its altitude, because of the intense insolation. When this air moves eastwards, even if it remains in the middle or upper atmosphere and does not descend into the Red Basin, it will be the cause of an "inversion", a reduced "lapse rate", or in other words a relatively warm layer of air at some height above the earth. Such conditions are meteorologically "stable", and convection currents do not readily form, while if they do form they tend to disappear when the inversion is reached. Under these conditions cumulus clouds and convectional rain are not likely. Thus any causes which promote a westerly circulation of the air over Szechwan, whether at lower or at higher levels, will tend to produce dry weather.

The writer has, indeed, observed that rain usually comes in Chengtu or Chungking with northerly or easterly winds. During a long, dry Spring which occurred in the Chengtu region, such winds were less common than usual, but, instead, southerly and south-westerly winds or calms were more common. And it could be seen, from the movements of cirrus and cirro-cumulus clouds, that the upper air was moving from the west or south-west. Cumulus clouds rarely formed, even in

warm, sunny weather; and if a few appeared in the middle of the day, they soon disappeared again. But shortly before the drought broke, the westerly cirrus ceased to be visible, and large convection clouds (cumulus) began to be common.

During this spring drought, it appeared that the "shielding" effect of the Tibetan air did not extend over the whole of Szechwan, but ceased approximately half-way across the Red Basin, between Chungking and Chengtu. Upland (terraced) paddy fields in the Chungking region were full of water when those nearer Chengtu were still dry; and when travelling by air from Chungking to Chengtu it seemed to be a fairly common experience to leave Chungking in wet, cloudy weather, and emerge into dry, almost cloudless weather about half-way between the two cities. During this as well as previous droughts, the rice crop was most seriously affected in the western part of the Red Basin, (excluding those areas such as the Chengtu Plain which have irrigation from mountain-fed rivers).

In normal Springs, and in Summer, the summer monsoon influence gradually strengthens and the rainfall increases, so that Szechwan, like the rest of China, has a rainy summer. The months of maximum rainfall vary in different parts of the Province, and since this has a direct bearing on the utilisation of the land, it will be discussed in detail later.

As Autumn approaches, the monsoon weakens, convection decreases, and the Central Asiatic anticyclone begins to exert its influence again. The rainfall decreases steadily from month to month, until the almost dry winter conditions are once more attained.

In southeastern China the typhoons which are especially common in late summer and autumn prolong the rainy weather into September or October, and it is possible that their influence extends to the borders of the Province, but not much further.

TEMPERATURE

As far as existing records go, they indicate that the mean temperature, and the annual temperature wave, are not very different in different parts of the Province within the "warm temperate zone" of altitude. The south is somewhat warmer than the rest, especially at Chungking, and, of course, temperatures become much lower at greater altitudes.

The mean monthly temperatures for central and southern Szechwan (means of the following stations: Chungking, Santai, Chengtu, and Anyo) are shown in Figure 1. It is evident that January is the coldest month; July and August are the two hottest, with June nearly as warm; and the other months may be grouped in pairs with similar mean temperatures: February and December, March and November, April and October, May and September. During August, the warmest month, the mean temperature is 26.6 °C, and during January the mean temperature is 7.0 °C. December to February may be regarded as the winter months; March to May, Spring; June to August, Summer; and September to November, Autumn.