

BOTANY.—*Agriculture and native vegetation in Peru.* O. F. COOK, Bureau of Plant Industry.

Alternation of forests with open grass lands or sparse desert vegetation is one of the most striking of the biological phenomena of tropical countries. Since the time of Humboldt many travelers in tropical America have sought to explain the presence or absence of the different types of vegetation by reference to differences of geological formations, altitudes, prevailing winds, or other natural features. More recent observations in Central America have led to the opinion that the chief factors governing the distribution of the forest vegetation are the agricultural occupation of the land and the continued action of fire on lands abandoned from cultivation.

There are reasons for believing that most of the forests of Central America do not represent original or virgin growth, but different stages of reforestation. Likewise most of the open grass lands and deserts appear to be consequences of the native system of farming—to be interpreted as artificial conditions rather than as natural features. The climatic, geologic, or topographic factors, though not without influence in determining the rate of reforestation, seem in general to have very little importance in comparison with human activities and exposure to fire. The complete reforestation of fireswept grass lands is a long and gradual process, but the successive stages can be recognized by taking account of the habits of the different kinds of trees.<sup>1</sup>

Opportunities of studying the relations of agriculture to forest vegetation under a different combination of natural conditions have been afforded during four months (April to July, 1915) spent in southern Peru and Bolivia as a member of the Expedition conducted by Professor Hiram Bingham, under the auspices of Yale University and the National Geographic Society, with the cooperation of the United States Department of Agriculture. Most of the time was spent in the region traversed by the Urubamba River and its tributaries, from the Pass of

<sup>1</sup> COOK, O. F. *Vegetation Affected by Agriculture in Central America.* Bull. 145, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1909.

La Raya, at an elevation of 14,000 feet, down to Santa Ana, at an elevation of 3000 feet, including a visit to the Panticalla Pass and the Lucumayo Valley. The region includes Cuzco, Pisac, Ollantaytambo, and Machu Picchu, the chief centers of the Inca and pre-Inca or Megalithic civilizations, and is of great agricultural and ethnological interest as the original home or place of domestication of numerous species of cultivated plants.

In this part of Peru, as in Central America, it appears that the present distribution of the principal types of vegetation is not a natural effect of altitudes, climates, or soils, but an artificial result of an intensive agricultural occupation of the land, extending through a long period of time. If we wish to think of an original condition, a biological background, so to speak, of the primitive agricultural civilization that occupied this region, we must imagine a country well covered with forests. The destruction of forests appears to have been carried much further than in Central America, in many localities to the complete extermination of all forms of arboreal vegetation. The chief considerations that seem to support these conclusions are stated in the following paragraphs.

#### BIOLOGICAL CONDITIONS FAVORABLE TO FOREST GROWTH

Though many districts are now entirely treeless and true forests are found in only a few localities, there appear to be no natural conditions that are definitely unfavorable to arboreal vegetation. Light, heat, and moisture are sufficient to support the growth of trees and there is ample fertility of soil, at the higher elevations as well as in the lower and more tropical valleys. In other words, there seems to be no climatic or biological factor to preclude the growth of trees on any part of the land surface except the bare rocks and snow fields at the summits of the high cordilleras.

From the positions of the moraine deposits and the lack of soil accumulations above them it may be inferred that the glaciers have receded in comparatively recent times, perhaps following the destruction of the forests. Some of the moraines

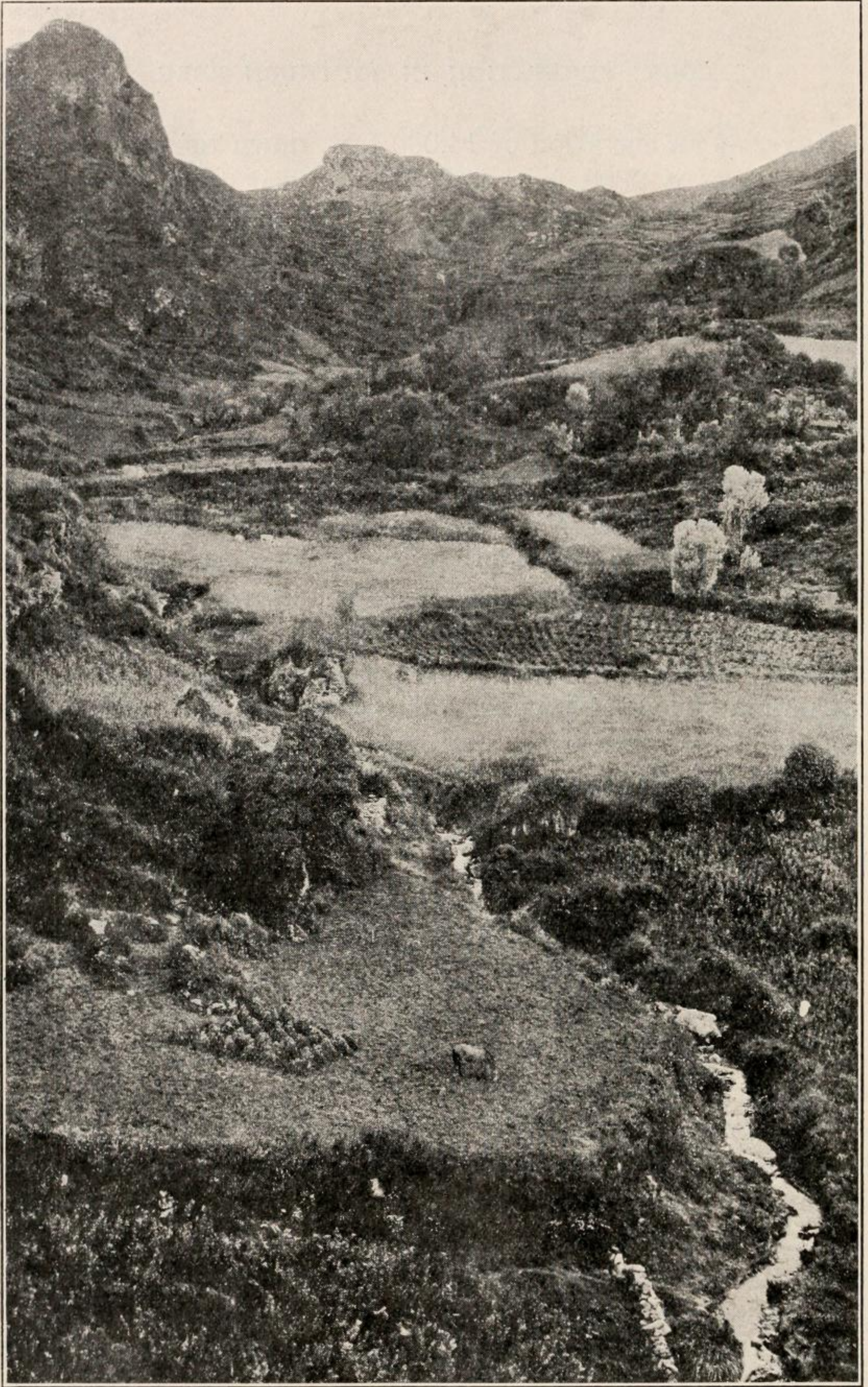


FIG. 1. Native agriculture in a branch of the Ushcopata Valley above Sicuani, Peru, at an altitude of nearly 13,000 feet, with fields of potatoes, barley, and broad beans, and remnants of the native forest flora—the white trees *quishuar*, the others mostly *queñuar* and *capuli*.

are as low as 9000 feet, with the present glaciers ending from 2000 to 4000 feet above. Under the Peruvian conditions it does not seem unreasonable to believe that the removal of a forest covering might tend to bring about a recession of the glaciers. Greater exposure of the rocky slopes would bring increased heat and dryness of atmosphere. Less snow would fall and the accumulations on the high summits would be exposed to longer periods of melting under direct sunlight.

As trees are often found above the moraines, there is no reason to doubt that the ancient forest covering extended up to the glaciers, as forests are known to do in other glacial regions. Several isolated tracts of forests have been found by Professor Bingham at very high elevations, even up to 15,000 feet. These high-altitude forests are of interest as affording the most definite demonstration of the fact that tree growth is not limited by elevation alone.

#### ANDINE FOREST FLORA

The possibility of a forest covering for all of the inhabited areas of this region is shown not only by the fact that trees grow when planted, but also by the presence of an indigenous forest flora whose different components are well adapted to the various natural conditions afforded by different exposures and elevations, up to the line of glaciers.

Two of the high-altitude trees, *queñuar* (*Polylepis*) and *quisuar* (*Buddleia*), have been noted frequently by travelers because they are often planted in villages or allowed to grow among the fields. (See fig. 1) Other members of the Andine forest flora of southern Peru are *lambran* (*Alnus*), *chachacoma* (*Escallonia*), *unca* (*Eugenia*), *lengli* (*Hesperomeles*), *quisca* (*Berberis*), *mulli* (*Schinus*), *chicjlluromay* (*Vallea*), and numerous other trees, including various arboreal *Compositae*. Several of the genera are represented by two or more species. Some of these, such as the species of *Escallonia*, are reported by botanical writers only as shrubs, but under favorable conditions they attain true arboreal proportions, especially at altitudes of 10,000 to 12,000 feet.

## REFORESTATION OF TERRACED VALLEYS

Though no original or virgin forests are now known to exist in this part of Peru on any lands that could be cultivated, reforestation with native trees is in progress in many places, notably in the valley above Ollantaytambo, and in the next valley to the west, leading up to the Panticalla Pass. In both valleys the growth of the native trees has progressed so far that

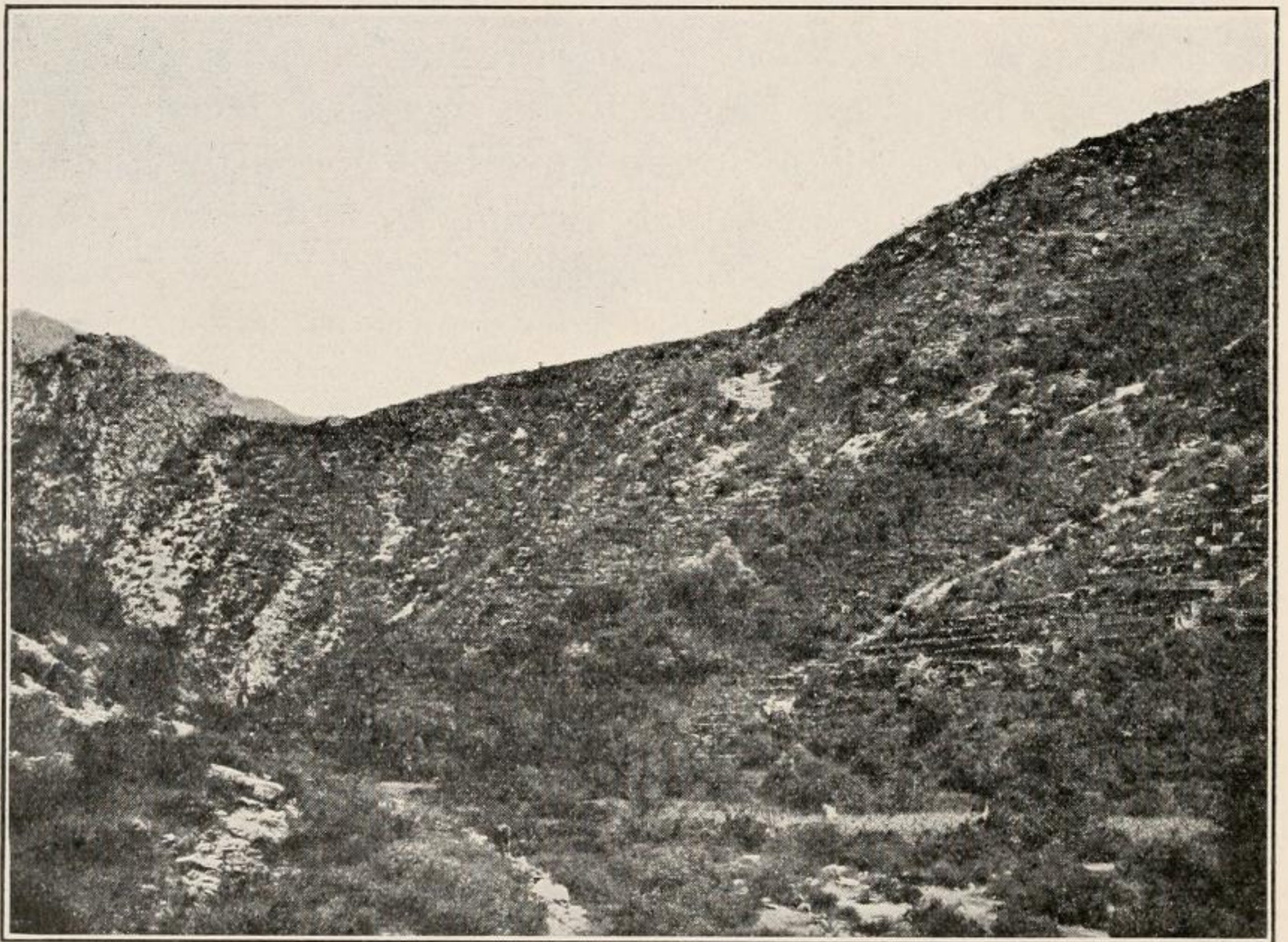


FIG. 2. Valley above Ollantaytambo, Peru, at an altitude of about 10,000 feet, showing terraced slopes partly overgrown with forests of native trees, including *quishuar*, *queñuar*, *lambran*, *unca*, and *lengli*.

genuine forest conditions have been restored, in the Ollantaytambo Valley covering several hundred acres, in the Panticalla Valley thousands of acres. Reforestation is demonstrated by the fact that the trees stand on ancient agricultural terraces supported by skilfully constructed stone walls. (See fig. 2.)

The survival of native trees in these valleys may be ascribed to the presence of lateral ravines too deep, narrow, and precipitous for cultivation. Such places may well have escaped the other-

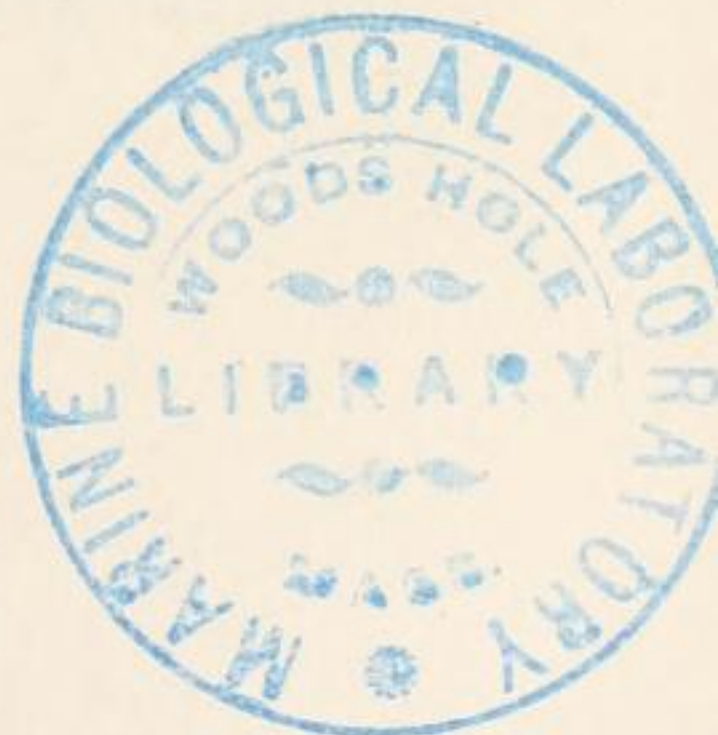
wise complete clearing of the land for agricultural purposes. Hardy types of woody vegetation, growing in the ravines and on the rocky slopes above, might survive even long periods of agricultural occupation of the terraced lands below. The neighboring areas might be seeded easily from the old trees. Such a ravine, leading up from the other side of the spur shown in the figure, is now heavily wooded and contains many well matured trees of the same species that now cover the terraces, although very few of the trees appear to be very old or to have reached the stage of natural decay. Some of the terraces in the Panticalla Valley are covered with much older trees than any found in the valley above Ollantaytambo.

#### HABITS OF SURVIVING NATIVE TREES

Although the genera of native trees, as mentioned above, belong to as many different families, there is a general similarity in habits of growth, in that all of them sprout readily from the stumps and endure repeated cutting. Seed is produced in a few years, if the sprouts are allowed to grow. The limitation of the present forests to such trees may be taken to indicate that persistent vitality was necessary to pass through the periods when these valleys were occupied by large agricultural populations, as shown by the extensive terracing of the slopes. A period of complete denudation of a valley would mean the extermination of all kinds of trees that were unable to sprout from the stumps, but trees like *Escallonia*, *Eugenia*, and *Schinus* might survive centuries of pollarding. The last is familiar as the "pepper-tree," now grown by thousands in southern California for shade and ornamental purposes. Other members of the Andine tree flora are even more attractive in appearance and promising for introduction into the United States.

#### DENUDATION OF UNCULTIVATED LANDS

The former presence of large agricultural populations accounts not only for the clearing of all the lands that could be cultivated, but also for the denudation of lands that were not capable of



cultivation. The growth of each native community means that supplies of fire-wood have to be sought farther and farther away. A large Indian town is usually surrounded by a broad belt of denuded lands, no forest being allowed to remain within two or three leagues. Judging the past by the present, a period of denudation of all the neighboring slopes must have followed the building of the extensive systems of terraces in the valleys about Ollantaytambo, Torontoy, and Machu Picchu. The country around these centers must have reached the same treeless state as the districts that now have large agricultural populations, such as the Vilcanota Valley and the slopes around Lake Titicaca.

#### REFORESTATION PREVENTED BY FIRE

In many localities cultivation is confined to the bottoms of the valleys or to the lower slopes, while the higher slopes have only a sparse covering of grass or low bushes. This gives the impression that the interior of the country is naturally treeless, like the desert regions along the coast. But the coast deserts are explained by the rainless climate, whereas in the interior the rainfall is sufficient to support forest growth.

The former cultivation of many of the higher slopes is indicated by the ridges and terraces that still remain. These show in turn the previous existence of forests, since forests must have preceded cultivation in order to accumulate soil and make it possible to clear the land by the primitive method of burning. This method is ineffective on grass lands, which have to be reforested before they can be re-occupied by a primitive agricultural people. At the higher altitudes grassy slopes are cultivated by spading, but this method is used only where turf is formed.

When treeless slopes are seen in tropical valleys meeting the tropical forest vegetation, it is plain that some active enemy of forest growth must be at hand, and this is fire. The fires that are set to clear land for cultivation commonly escape and overrun the slopes above. As the grass-covered slopes are used only for grazing, no effort is made to protect them from fire.

## FORESTS IN INACCESSIBLE PLACES

Trees are often found growing under very unfavorable natural conditions, in places that are too steep, rocky, or isolated to be cleared for cultivation or for providing fuel. In the lower Urubamba Valley it was observed that the driest and rockiest hillsides in the vicinity of Santa Ana are covered with forests of *huillca* (*Piptadenia*) and other tropical trees, while the smoother and more fertile lands on either side have no trees, but a heavier growth of grass.

Tree seedlings often appear in grass lands, but are killed when fires sweep over them. Hence, the forests are confined to the rocky slopes as long as the adjacent grass lands are visited by fire. Grazing reduces the danger of fire, and this assists in reforestation; but the forests themselves may burn after sufficiently long periods of drought. In the lower Urubamba Valley, at altitudes of from 4000 to 8000 feet, the forests have been burned on many slopes altogether too steep for cultivation. This not only kills the trees but often has the effect of loosening the soil and rocks, causing destructive landslides.

## PAUCITY OF THE HUMUS FAUNA

Another indication of the more complete denudation of this region in former times is the paucity of the humus fauna, comprising the insects, millipeds, centipeds, and other small animals that live normally in the upper layers of the soil. These creatures become very abundant under conditions that afford permanent moisture in the soil, but are killed when the land is burned over or parched by severe drought. In southern Peru the humus-inhabiting animals are everywhere extremely scarce, and often lacking altogether. The number of species is very small, as well as the number of individuals. Of millipeds only three orders are represented, *Merocheta*, *Anocheta*, and *Diplocheta*; in many localities only *Merocheta*, and most of these of Antarctic types rather than tropical. The three orders of very primitive arthropods, *Symphyla*, *Rhabdura*, and *Dicellura*, are present, but were nowhere found in abundance, even in places



where reforestation has advanced so far that ample deposits of humus have accumulated. Humus-inhabiting insects of other orders, including the Thysanura and Collembola, are also few.

#### ABSENCE OF PALMS IN TROPICAL FORESTS

The flora of the valley between San Miguel at 6000 feet and Santa Ana at 3000 feet is distinctly tropical, and large areas are forested, but not with original or virgin growth. That reforestation is still far from complete is shown by the general scarcity and often complete absence of palms. Instead of a normal palm flora, no locality in the Urubamba Valley was found to have more than two species, a large *Geonoma* and a small *Chamaedorea*.

This deficiency seems the more significant because the natural conditions are extremely favorable and the palm flora of the adjacent regions of South America is one of the richest in the world. The original palm flora of this district can not be estimated at less than a dozen species, and may have included two or three times that number. But denudation would involve a complete extermination of the palms, and these plants are very slow to return, even after forest conditions have been re-established.

#### RECONSTRUCTION OF THE FLORA AND FAUNA

In view of these indications of prolonged interference with the original conditions of plant and animal life it does not seem reasonable to ascribe the present distribution of the native vegetation entirely to differences of soil, temperature, altitude, or rainfall. An ecological account of the Peruvian flora that ignores the factor of human activity, as in the treatise by Weberbauer, does not convince. To present an adequate conception of the native flora and its relations with the external conditions would require a process of reconstruction, a careful collecting and piecing together of the parts of the flora and fauna that are left. Then there would need to be a careful comparison with the floras and faunas of neighboring regions that were not occupied and denuded by the ancient civilizations, if such regions can be found. This would give a better appreciation of

the extent to which the presence of man has modified the original conditions of the environment along the eastern slopes of the Andes.

#### AGRICULTURE AT HIGH ALTITUDES

Corresponding with the wide range of altitude there is great diversity in the forms and habits of the wild vegetation and in the agricultural arts of the native inhabitants. In the lower valleys where corn is the principal crop the method of clearing the land and the relation of agriculture to the native vegetation are much as in Central America.

The high plateaus of Peru, where the native agricultural population is now chiefly centered, are unlike any part of Central America, the nearest approach being found in the tablelands of Guatemala. In Central America cultivation is hardly carried above 8000 feet; whereas in Peru potatoes and other Andine crops are commonly grown at 13,000 feet and in some places at 14,000 feet. Moreover, it is in these elevated districts that the native system of agriculture attained its highest development and was least disturbed by the Spanish conquest.

#### CONCLUSIONS

The native agriculture of southern Peru is self-limiting. Cultivation may be maintained for longer periods on the tablelands and higher slopes, but when the soil is once exhausted and removed by erosion there is less prospect of renewal through reforestation than at the lower elevations. Although under the high altitude conditions the accumulation of soil goes on to a certain extent in open grass lands, without the aid of forests, such gains evidently do not make good the losses incidental to cultivation. Large areas of the higher slopes that appear to have been cultivated intensively in former times are now completely sterile and abandoned.

Thus Peru may be said to afford even more striking evidence than Central America of the fact that the primitive agricultural civilizations were not permanent, but of limited duration. Eventually the soil became unsuited to cultivation by the native methods.