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The Economics of Water Supply and Control:

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Lima, Peru

PERU'S WATER RESOURCES

ALTHOUGH situated in the tropics, Peru lies partly in one of the most arid zones in South America, the Pacific coastal area. Economically, however, that area is the country's most important agricultural region. In those parts of the country where rainfall is abundant, topography rules out the efficient use of rain water. This helps to explain why the country, with its area of 1,249,049 square kilometres (309 million acres), has only somewhat less than 1,800,000 hectares, or 18,000 square kilometres (4·4 million acres), under cultivation—in other words, less than 1·5 per cent. of its area. The area of land *per caput* is progressively reduced and amounts at present to scarcely one-sixth of a hectare (less than half an acre) per inhabitant. To maintain this ratio the cultivated area would need to be increased this year by 50,000 hectares, and in succeeding years the increase would have to be accelerated to keep pace with the population increase which at the present rate is about 2·8 per cent. a year. These facts serve to bring out the importance to the country of the proper administration and utilization of its water resources and, in the eastern parts of the country, the building of access roads by which new areas may be made accessible for cultivation.

For a better appreciation of the situation there follows a brief description of the topography of the country and of its water resources and rainfall conditions. Afterwards we shall deal with the utilization of its water resources, with their administration and control and, finally, with the irrigation works and improvements which the country needs. We shall thus arrive at an appreciation of the relative economic and social advantages of the investment of given amounts of capital in large-scale irrigation as against investment of a comparable amount in a number of corresponding smaller projects—bearing in mind, however, the great diversity of conditions obtaining.

The Andean range and its water resources. The range of the Andes which forks at different latitudes into two or more chains runs across Peru in the general direction of SSE. to NNW. Starting from Mount Porco in Bolivia in the south, two chains separate to form the plain of Lake Titicaca or Collao—the Altiplano—to join again in Mount Vilcanota near Cusco, whereupon they again divide and then join in

Mount Pasco. Farther north three chains form the so-called western, central and eastern Cordilleras of the Andes. The latter loses height and finally disappears in Ecuador, while the two former join in the Loja Peak in that country.

In addition to these main ranges, the chain known as Andes Conomamas forms north-east of Cusco and ends not far from the Amazon River. North-east of Mount Pasco the western range divides into two chains: the White or Snowy Cordillera, which has the highest peaks, and the Black Cordillera. Together these delimit the extraordinarily beautiful region of Callejon de Huaylas. In the valley between these two chains runs the Santa River, one of the more prolific and regular water courses of the Peruvian coastal region. Work to harness it for hydro-electric purposes began last year.

A relief map shows Peru to be divided into three distinct regions: the coastal, the *Sierra*—i.e. the mountain region proper, and the *Montaña*—that is, the region of woods and tropical forests. Each of these has its own distinct climate, fauna and flora.

The coastal region extends from the shores of the Pacific to the foothills of the western Range (Cordillera) of the Andes, rising to an altitude of about 1,200 metres (3,900 feet) above sea-level. It constitutes a narrow belt, more than 2,200 kilometres (1,375 miles) long and varying in depth from 80 to 180 kilometres (50 to 113 miles). It is relatively flat or has low gradients near the river mouths and then rises abruptly.

The Sierra, or mountain region proper, rises on the western side of the Andean range at the altitude mentioned above and ends at its eastern slope at about 1,350 metres (4,392 feet) above sea-level. The region includes three areas—the cis-Andean which faces the Pacific, the inter-Andean which lies between the various mountain ranges, and the trans-Andean which faces the Atlantic.

Thirdly, there is the *Montaña* or forest region which extends eastwards. It starts from an altitude of about 1,350 metres (4,392 feet) and covers more than two-thirds of the country's land surface.

The Andean range also determines the division of the country's water resources. There are three large catchment or drainage areas: those of the Amazon or Atlantic, the Titicaca or Collao and the Pacific.

The Amazon catchment area is the largest, with an area of approximately 995,000 square kilometres (384,000 square miles). It includes all the great rivers which ultimately drain into the Atlantic. Their

sources are found in the inter-Andean or trans-Andean areas of the Sierra or in the forest region.

The Titicaca catchment area is the smallest. It is a closed area of about 50,000 square kilometres (19,000 square miles) and includes all the rivers which flow in the high plateau of Lake Titicaca or Collao, an area which is enclosed by the two mountain ranges of the Cordillera and Vilcanota massifs.

The Pacific catchment area includes all the rivers which, theoretically, shed their waters into the Pacific. These rivers are short in length but steep in gradient, which results in rapid and irregular flow, so that the rivers become torrents at times of heavy rain, sometimes drying up completely when there is drought in the water-collecting area. Jointly these rivers drain an area of about 140,000 square kilometres (54,000 square miles) on the western escarpment of the Andean range and its foothills. Since that area covers 250,000 square kilometres (97,000 square miles) it will be appreciated that 44 per cent. of it is completely dry.

Annual rainfall and water resources. Water resources as such are determined by the quantity of water which collects in a drainage area, whether as a result of thaw of glaciers, filtration, or directly by way of rain—which factors account, however remotely, for rivers.

In Peru, owing to the influence of the Andean range, ocean currents and predominating winds, the laws which govern rainfall are quite distinct in each of the three natural regions into which the country divides, and this reflects also on the relative importance of the three very large drainage areas. The coast, which because of its geographical situation and its proximity to the ocean should enjoy a truly tropical climate and therefore abundant rain, is, in fact, part of the driest and most arid zone in South America. It has an annual rainfall ranging from 0 to 25 centimetres (9·75 inches). Without delving deeper into this apparent anomaly it may be stated that there are three principal causes: (1) the presence of the Andean range which is a barrier to the rain clouds swept across by the east winds from the Atlantic; (2) the cold oceanic current known as the Peruvian or Humboldt current; and (3) the Pacific trade winds which blow from the south-east to the north-west—that is, away from the coast—and carry with them condensation formed over the ocean.

But rainfall conditions are different in the north, in the area closest to the Equator, as a result of the warm ocean current known as the Corriente del Niño [Counter current] which in some years—and in

cycles of a certain regularity—makes its effects felt farther south, causing exceptionally high and damaging rates of rainfall. This occurred in 1858, 1871, 1891 and 1925.

The mountain region is, normally, a humid zone, precipitation varying from 25 centimetres (9·75 inches) to 2 metres (78 inches). As a result of this the clouds carried by the dominant east wind from across the Atlantic condense in the form of rain. The zone which has by far the highest rate of rainfall is that in the area of the escarpment of the western range, at the tree line. It diminishes towards the west where light rainfall, under the influence of the negative factors which cause the drought on the coast, begins regularly at the end of October or the beginning of November and ends in April or May.

In the *Montaña* or forest region which has a tropical climate, rain falls during the greater part of the year; but in the summer (which for this reason is there called winter) the rains are torrential and swell the rivers to an extraordinary degree, producing floods and inundations.

The relative importance of the three catchment areas. To form an idea of this, it is not enough to delimit the areas where the rivers forming these basins originate, and to have data regarding the extension of the drainage areas and of the quantity of rainfall in each one. Unfortunately, there are no records of the water flow in the various rivers, with the exception of those in the coastal area (which is agricultural and economically the most important) which might have formed the subject of systematic study.

However, to convey the considerable difference which obtains between the river basins of the Pacific and the Atlantic, it may be useful to mention that the total discharge of all the rivers of the coastal region—according to data collected by the hydrographic survey and measurement stations set up in the upper river valleys of the region—reaches a figure of 40,000 million cubic metres (1,400 thousand million cubic feet) a year, which is equivalent to an average continuous discharge of 1,250 cubic metres (44,144 cubic feet) per second; whereas the Amazon River, where it leaves Peru, carries a volume of 20,000 cubic metres (706,290 cubic feet) per second—in other words sixteen times more than all the rivers of the coastal region. Even so, it should be noted, the Amazon River does not drain all the water on the Atlantic watershed.

These data are supplemented by the water resources and rainfall maps of Peru (Fig. 1). These maps show clearly that the Pacific plain

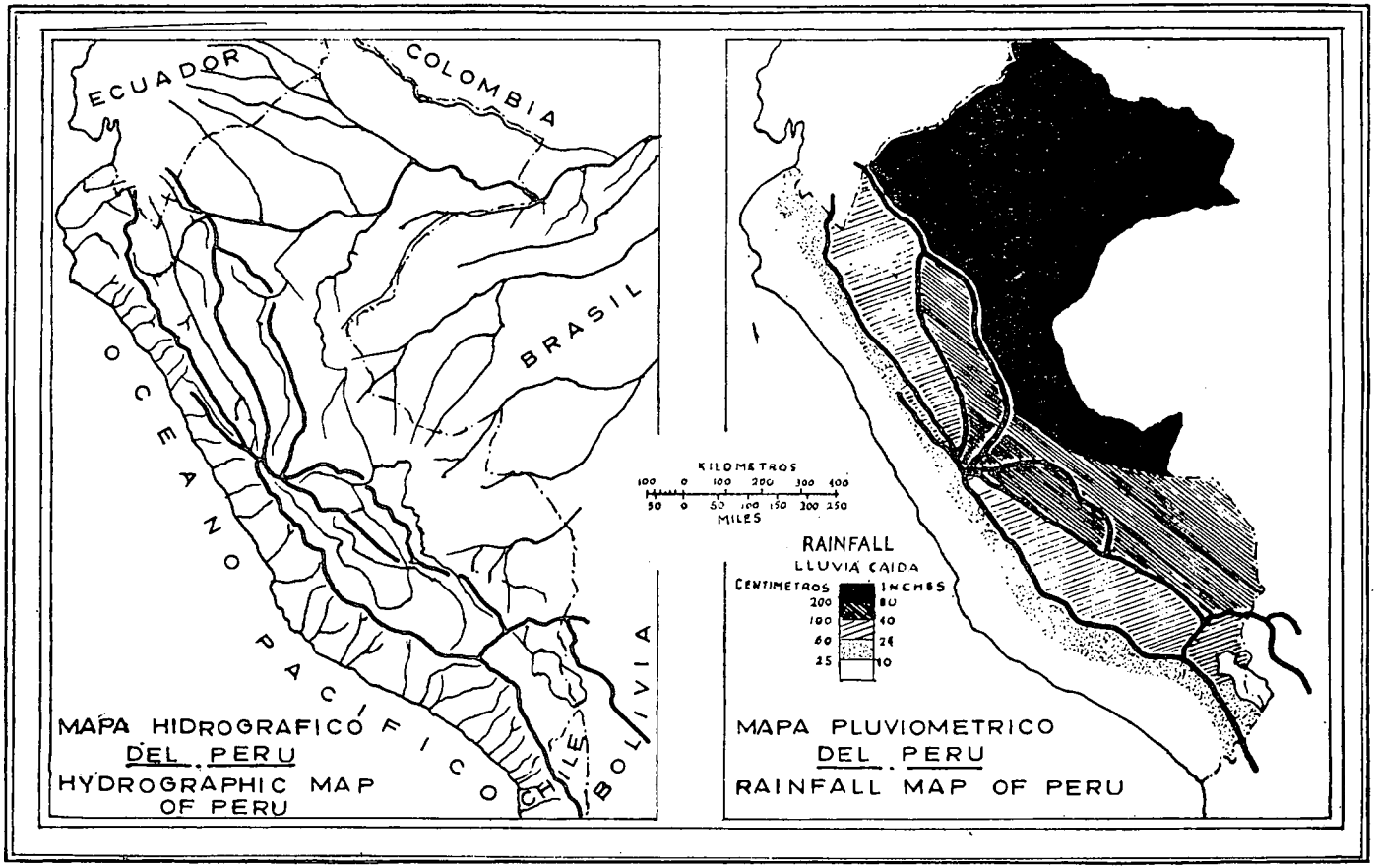
ECUADOR
COLOMBIA
BRASIL
OCEANO PACÍFICO
CHILE
BOLIVIA
MAPA HIDROGRAFICO DEL PERU
HYDROGRAPHIC MAP OF PERU
KILOMETROS
100 0 100 200 300 400
50 0 50 100 150 200 250
MILES
RAINFALL
LLUVIA CAIDA
CENTIMETROS
INCHES
200 80
100 40
60 24
25 10
MAPA PLUVIOMETRICO DEL PERU
RAINFALL MAP OF PERU

FIG. 1

is not the most important area from the point of view of water resources, and that the western Andean range—the highest peaks of which rise to an altitude of 6,588 metres (21,411 feet) above sea-level —do in fact constitute the continental divide.

Utilization. The three main uses of the water, in order of importance, are: inland navigation, generation of power and irrigation of agricultural land.

In the forest region about 8,000 kilometres (5,000 miles) of our water courses are used for river navigation which constituted, up to the development of air services, the only effective means of long-distance transport. It was, and continues to be, extremely useful in the exploitation of the region, however primitive such exploitation may be. The potentialities of utilizing water for generating power have always been based on rather optimistic evaluations. Figures ranged round 120 million kilowatts, since estimates were based not on economic criteria, and even less on technical criteria, but rather on mathematical calculations taking utilizable energy as being equal to the potential of the rivers on the basis of minimum flow and their total gradient over the entire course of the rivers.

We cannot, of course, accept this figure, although we are prepared to grant, with *Electricité de France*, who have made a survey for the Peruvian Government for a plan for the supply of electric energy, that 'Peru is a country exceptionally endowed with hydro-electric wealth'. There is disagreement among the specialists concerning practical possibilities of hydro-electric utilization of the rivers. Fifteen million kilowatts may be taken as a conservative estimate, since the known, surveyed and planned potential comes to more than 50 per cent. of this figure, viz. 7,693,000 kilowatts.

The actual supply is very small, notwithstanding the remarkable increase of equipment installed during the last two years: in 1956 the generation of electricity amounted only to 230,800 kilowatts, and to 386,900 at the end of 1958. This shows that during these two years there was an increase of 67·63 per cent. By the end of 1962 an increase of at least 211,200 kilowatts is envisaged on the basis of work already in progress or about to begin. These figures are indicative of the progress of industrialization, although it represents less than 8 per cent. of the potential surveyed and is less than 4 per cent. of the usable potential.

Although, basically, the utilization of the river water is for agricultural purposes, not all the available resources are, in fact, so used. As

was stated earlier, the country's cultivated area amounts to scarcely 1,800,000 hectares (4·4 million acres), which is less than 1·5 per cent. of the land. A part of this area receives its water supply by artificial irrigation (irrigation channels or pumped supplies taken from rivers) and a part receives its water supply from direct utilization of rain water for dry farming, the proportions being 80 per cent. and 20 per cent. respectively. Thus, as a result of irrigation, some 1,460,000 hectares (3·6 million acres) of land are made available for the extension of the cultivated area.

The greater part (by value) of the agricultural products of the coastal valleys and almost the entire crops of the mountain and highland regions are used for consumption—largely for direct use by the producer. But a part of the agricultural crops of the coastal valleys consists of products for export, notably sugar and cotton, the latter being a variety for which there is a considerable demand on the world market. The coastal valleys have the best communication facilities, proximity to the ports, &c., so that the country's main economic activities are concentrated there. This accounts for the wide extension of cultivated land through irrigation, amounting to almost 50 per cent. of the land on the Pacific slope, or 500,000 hectares (1,236,000 acres); in the mountain regions, although 940,000 hectares (2,323,000 acres) are artificially irrigated, this is a much lower proportion. Despite the greater agricultural development of the coastal belt, the water of its rivers is far from being fully utilized. Between 75 and 80 per cent. of the 40,000 million cubic metres (1·4 billion cubic feet) of the annual discharge of water of these rivers is lost in the Pacific Ocean. The figure of 75 per cent. is based on 1927 estimates. That of 80 per cent. is based on recent studies of the Inter-American Co-operative Service of Food Production (S.C.I.P.A.). These figures, however, should not be taken to suggest that the irrigated area in the coastal region could be tripled or quadrupled by irrigation.

Peru is manifestly a country of contrasts. The country has a considerable land area, but a population of little more than 10 million, hence an apparently very low density of population. However, since only 18,000 square kilometres (4·4 million acres) are under cultivation, the actual density of population, based on the country's land area in economic use, is thus over 555 inhabitants per square kilometre (2·3 inhabitants per acre) of agricultural land. More than 60 per cent. of the economically active population are engaged in agriculture; the area of cultivated land, however, is very small. One of the world's

most important river systems, that of the Amazon, originates in Peru, but its waters are not utilized there, or only to an infinitesimal extent. Its most important agricultural area economically is situated on the slopes of the mountain range which has the lowest rainfall. Add to this that the rivers of the coastal belt with the most copious and regular flow are not at all, or quite inadequately, utilized. This situation, which may well be regarded as disastrous, is due not only to the causes referred to above, but also to the country's topography. A system of torrent water discharge prevails on the Pacific escarpment, and prevents both the irrigation of the extensive *pampas* (tree-less areas) or prairies in the lower coastal region and also, to all intents and purposes, renders water-storage works practically impossible. Such water storage would require dikes and dams of great height but of very small capacity or, in the case of those rivers of the region which have a larger water-carrying capacity, would render water utilization difficult since the piped flow would necessitate costly and difficult works. Two sets of data may help in an appreciation of the negative factors arising from topography:

1. The Autisha Dam on the Santa Eulalia River—a tributary of the River Rimac on which lies Lima, the country's capital city—rises to a height of 140 metres (455 feet) and has a storage capacity of only 20 million cubic metres (706 million cubic feet).

2. Studies for the irrigation of the Majes, Vitor and La Joya pampas from the Majes River, one of the main water courses of our coastal region, have shown that ninety-two kilometres of tunnels would be needed before the water could reach the first acre of arable land.

The mountainous region on the other hand where, as has been shown above, the rainfall is high, lacks valleys in the sense of flat or low gradient areas, with the only possible exception of the Cajamarca or Mantaro valleys. The cultivated areas are on the slopes of the high peaks or certain stretches of the passes, while in the valleys mountain torrents gush. Sometimes there are small flat areas near the junctions of these torrents. The only larger flat, or relatively flat, areas in this region are at about 3,500 metres (11,375 feet) above sea-level, where cultivation is all but impossible. The level stretches known as *puna* or *jalca* are natural pasture consisting of a kind of small, reed-like plant called *ichu-ichu*.

In the forest regions, where there are vast areas of level ground, the torrential rains and the consequent soil erosion constitute serious obstacles to the agricultural use of the land. Its organized use for

agriculture would be technically and economically possible only if forests were cleared and contour farming established or maintained by means of protective plantations set up for the purpose of conserving what agricultural soil there may be. Such soil is usually very shallow and originates from eroded ground higher up. In this way the soil would be gaining a hold between the roots of age-old trees growing in these areas. Furthermore, there is a need for solid access roads to render it possible to transport agricultural produce from these areas and to give some freedom of movement to the settlers. This region clearly constitutes a reserve of land and water resources which the country will have to incorporate in its economy.

Administrative practices and control In this respect also there are substantial differences not only as between the three regions into which the country divides but also within each one of them. This is due to the existence of legal provisions, the letter and the spirit of which have to be observed. These concern ancient rights of water distribution. They have to be observed however greatly conditions and circumstances may have changed since these provisions were first decreed. What is even more serious is that these legal provisions enforce the observation of what are somewhat euphemistically called 'ancient uses and customs'—which tend to be ways of sanctioning abuses. This situation prevails despite the remarkable progress achieved in the administration and control of water during the present century.

To give even a brief historical account of the mass of legal provisions issued first during the colonial period at the time of the viceroys, and then by various successive Peruvian governments after the country became independent, would require too many pages. It would help, however, to explain the situation at the beginning of the present century. At that time the constant increase of the cultivated area, especially in the coastal region, made it more difficult from day to day to distribute water supplies. The matter was further complicated by the almost deliberate confusion of legal titles to irrigation; by the intervention of local authorities (which was certainly not inspired by a desire better to serve public interests); by the continued existence of colonial rules and regulations which it was attempted to make generally applicable, although they were, clearly, already unworkable; and by the existence of isolated laws and by-laws in particular areas, all of which constituted a disconnected and often contradictory mass of provisions which made it necessary to pass a general Water Act.

Unfortunately, the Water Code which was promulgated in 1902

was an unsatisfactory adaptation of the Spanish Act of June 1879 and attempted to transplant irrigation institutions which in Spain had a certain tradition behind them but which, in Peru, were doomed to failure. The chief defect of the Water Code lay in the authorities which were made responsible for administration. The corporation of those with interests in irrigation, the administrators appointed by that corporation, and the regional *syndicates* which had controlling powers, had a *raison d'être* in Spain, where landownership was concentrated in few hands and where this was one of the most aristocratic and traditional of administrative methods for dealing with irrigation. There this system may have provided admirable and fair administration; but in Peru these institutions were alien and tended to favour vested interests.

What happened in fact was that water administration was handed over to the large agriculturists, since land area was taken as a basis for computing voting power. This led to great abuses particularly since, in many agricultural districts, the water administrators directed their own activities by means of 'ordinances' promulgated by the corporations on the basis of this voting system; and these ordinances empowered them to distribute water in accordance with the 'state of crops', thus introducing a factor of subjective appreciation working in favour of those with heavy voting powers.

This state of affairs which existed in relatively recent times, happily did not last long. Already in 1911 the government saw itself compelled to intervene to eradicate these corrupt practices which had led to protests. Indeed, the reaction of the small agriculturists who found themselves deprived of water, took the form of armed rebellion in a northern province. The corporations of those interested in irrigation were pushed aside—a solution which infringed the law but was received with satisfaction in the main valleys. The corporations were replaced by technical committees constituted by civil engineers with no direct or indirect interest in water supply. This arrangement was *ex post facto* regularized by law. The impartiality of the officials in their work on the irrigation boards was assured by a provision that 'if more than three of the determinations of a technical committee were countermanded in a year its staff was to be replaced'.

When water distribution was in the hands of local authorities, tribunals and corporations of those interested in irrigation, the general allocation of water in the valleys, which was accompanied by mensuration of all outlets and of each one separately, was an event which took

the form of a judicial or administrative proceeding. It was done by visual inspection under the superintendence of judges, notaries and experts. On the other hand, for the technical committees, these allocations were and are a matter of routine and, sometimes, in accordance with communications from conservancy stations, collecting centres, &c., they have to be carried out several times in the course of a day, as soon as a change in the water-level of a river is observed. Statistics show an increase in cultivated area in the coastal region. This is not fortuitous, but results from a better distribution and supply of water and from the greater frequency of mensurations and the consequent action taken, as well as from more effective control, properly organized.

In addition to their greater general efficiency, the technical committees applied scientific methods to water-collecting systems by constructing water outlets, automatic-flow controls and mensuration systems using instruments to gauge the velocity of the current, and also by constructing weirs, metres of the Parshall type and other appliances. Their efficiency has been proved. Furthermore, instruments for automatic measurement of the water-level have been installed and have facilitated the instantaneous calculation of the discharge of water.

The Act under which the technical committees were set up and its amendment which led to the creation of technical departments, met a great need. They were enacted in response to the necessities of the coastal area. The jurisdiction of these bodies extends from the source to the mouth of rivers, to their tributaries, and to canals linked with them as well as to the waters from any other natural source for public supply. Under this legislation provisions of the Water Code applying to the rest of the country were repealed. Thus the irrigation arrangements in the mountain and forest regions, particularly in the upper reaches of the rivers in the forest region, became obsolete. The government was obliged, therefore, to issue regulations by decree, to extend the powers of the technical departments to certain valleys in the mountain region, while the remaining areas were made subject to special administrative provisions under the Ministry of Development and Public Works.

In more recent times—in 1928 in the valleys of the province of Lambayeque and in 1954 in the Piura Valley—the so-called volumetric system of irrigation was adopted. It indicates a uniform supply, in terms of volume, per unit of surface; it should, however, be noted that uniformity does not mean that the same unit has been adopted in

these valleys. This system of water distribution marks considerable progress, particularly in the Piura Valley, where its adoption led to works which assure a greater flow of water in the Piura River. The result achieved in Piura, by the adoption of the system, has led to the abandonment of a complex system of irrigation priorities which were based on the origin and antiquity of titles and rights. The new system has ensured that all the holdings served—a total of 31,500 hectares (77,865 acres)—have the same opportunities for irrigation, without prejudicing anyone's rights. This result would justify the extension of the system to the rest of the country.

To do so, however, will require the passing of a new Water Act which should be modern and flexible in conception and, moreover, should both in the letter and the spirit embody the constitutional principle that water belongs to the state, the state alone conceding its use and supply, keeping in mind the public interest. The state should take into account the quality of the land, its water-holding capacity, the state of drains, the type of crops grown, &c., and proceed to a general clarification of rights and titles in the light of these essential factors and circumstances. In this way a basic transformation should be achieved.

Irrigation and its improvement. Relationship to geographical requirements. Reference has been made to the difficulties of water utilization in Peru. It should now be added that the inhabitants of the country from prehistoric times have found ways of meeting the challenge of mountainous terrain and water supplies. They overcame the difficulties and triumphed in the struggle against nature by dominating it; they canalized the waters of rivers and mountain streams, they tapped underground water to cultivate the land and to raise crops needed for sustenance. They were, in the words of Professor Luis E. Valcarcel, a famous Peruvian historian, 'without land and without water, the greatest agriculturists in ancient America', because the utilization of water requires courage and enterprise; and in order to have agricultural land it is necessary to make it or, in other words, to transform ground that can be ploughed into agricultural land.

The ancient Peruvians built remarkable irrigation systems on the coast, outstanding among which are the flooding canals in the present-day provinces of Lambayeque and La Libertad in the north. With astonishing knowledge, they were able to link the water resources of neighbouring rivers so as to irrigate the intervening pampas. In many other places on the coast and in the mountains there are remains of

great canals, many of them built with rubble or filling material on the slopes of the high mountains. These works were possible under the labour system of that period, Nor should the aqueducts of Nasca be forgotten. They prove that the ancient Peruvians knew how to utilize shallow underground water. These achievements prove also the ancient Peruvians' knowledge of hydraulics, which was highly advanced and by which they counteracted the excessive gradient of the pampas and avoided erosion. Works showing the use of river deposits to render land fertile can still be seen at Chanchan, near Trujillo, as can the stakes, indicating gradients which were found at the bottom of the ancient Inca canal near Corrales, and the instrument which must have been a primitive spirit-level which may be seen in the Regional Museum at Huarez.

The ancient inhabitants of Peru built in the mountains the most remarkable terraces which are still used today. Some of them, such as those of Yucay (Urubamba, Cuzco) in the 'Inca's gardens', are most artistic in design. Terrace cultivation had the dual purpose of avoiding soil erosion which would otherwise constantly reduce the depth and productivity of the land, and of conserving soil water by making it trickle slowly across the land and feed rivers which thereby acquired a less torrent-like character.

During the colonial period and the first years of the Republic—during virtually the whole of the nineteenth century—the Peruvian tradition in matters of irrigation was only sporadically remembered and no fresh efforts were made. During the present century there has been a reaction: more and more land has been incorporated in the country's agricultural area, but not at the rate at which population has increased. Since 1932 more than 100,000 hectares (247,100 acres) have been added to the cultivated area, more than 75,000 hectares (185,335 acres) in the coastal area. This is important, since it is land definitely won. This cannot be said of irrigation works in the mountain regions which consist mostly of improvement by irrigation or, perhaps more accurately, by changing the method of irrigation by making better use of rain water and transforming dry farming by permanent artificial irrigation through the use of drainage.

Thus Peru is taking up the challenge of nature but, as already stated, a considerable effort is required. To do no more than maintain the present area of cultivated land *per caput*, an annual increase of over 50,000 hectares (124,000 acres) of cultivated land is required.

Irrigation works and the improvement of irrigation. In our preparation

to face this great problem, a series of provisional or final irrigation and/or land-improvement schemes are being studied, in addition to those already being carried out. They cover 230,718 hectares (570,135 acres) of permanent irrigation schemes of which 21,422 hectares (52,986 acres) are in the mountain region. Further, there are 47,500 hectares (117,380 acres) which are irrigated during the period of abundant water supply—that is to say, they are occasionally irrigated —and 187,508 hectares (463,364 acres) in the coastal area which are irrigated at present by the system of water-discharge imposed by the character of the mountain torrents.

The irrigation works in the mountain region are in fact, as already pointed out, land-improvement schemes. Their execution can be justified in the light of the need of the small Andean or inter-Andean valleys' requirements of water at the right time and in the right quantities to produce vital food crops. Many of these have at present to be imported, thereby aggravating our shortage of foreign currency. The irrigation-improvement works in the coastal area are likewise justified, although those not familiar with the problems of Peruvian agriculture wrongly consider them to be exclusively profiting private individuals. These works lead in fact to higher productivity and thereby to the creation of wealth and to other developments which increase the yields of certain taxes. But even more important, if these land improvements had been carried out in time, the high concentration of landed property in certain coastal valleys could have been avoided. The history of our agrarian system even during the present period has shown that one of the more important factors which lead to such concentration is the farmers' need to have a substantial share of irrigation water supplies, particularly in periods of drought. The justification for irrigation works is obvious in the light of a study of the present situation.

The estimated cost of all the irrigation works studied lies between U.S. $230 and $260 million. This figure makes allowance for the depreciation of the Peruvian currency and for rises in prices and wages and hence of the manufactured products of the country. Such a sum cannot be considered excessive, in the light of the country's requirements and of the urgency of dealing with the problem of land shortage, or at least alleviating it. It should be remembered in this connexion that the Government of Egypt is attempting to obtain for investment the sum of U.S. $1,300 million—about five times the sum required in Peru to build the Aswan Dam for the purpose of irrigating 490,000

hectares (1,210,860 acres), about the same area as it is proposed to irrigate in Peru, if the acreage covered by improvements of irrigation are included.

Large-scale v. *small-scale irrigation projects.* A comparison between the economic and social advantages to be derived from a given investment in one large irrigation project as against a number of small schemes can hardly be conclusive. Peru is a complex country which stretches for 2,200 kilometres (1,375 miles) and conditions differ not only between its three topographical regions but between the areas within them, even though they may be relatively close to one another. The quality of soils, the ease of access to water courses, altitude and differences in climate are natural factors which determine the possibilities of raising different crops of varying economic importance. Furthermore, when an attempt is made to compare social advantages, the influence of demographic pressure, or the relationship between population density and the area of cultivated land, cannot be omitted. If it is low in the country as a whole, it differs, nevertheless, in the various parts or local government areas.

In order to meet the difficulties which are inherent in any comparison of widely differing conditions, an attempt is made here to confine the comparison, as far as possible, to schemes in a single province where conditions are fairly homogeneous. The province of Arequipa has been chosen as it has, on the one hand, the largest irrigation scheme under consideration, the irrigation of the pampas of Majes and Siguas, and, on the other, three smaller schemes, the irrigation projects of Cuno-Cuno and of the Arma River area, and the extension of the irrigation schemes of the La Joya pampas.

According to official data (all except those referring to the La Joya scheme are taken from a 1956 publication of the Ministry of Development and Public Works: Water and Irrigation Department) the following are the areas proposed for irrigation and the estimated costs expressed in Peruvian currency. (The figures referring to the Arma River area are provisional.) See page 478.

These figures show that the cost per hectare of irrigating the Majes and Siguas pampas is S/.15,496.01, whereas for the other three irrigation schemes it amounts to S/.16,446.46 which, at the 1956 exchange rate, represent £118 sterling and £126 per acre, respectively. The costs are high, particularly as they represent only the costs of civil engineering works arising from taking the water to the upper ends of the parcels. Further, the investment required to convert ploughable

into cultivated land will be at least as high, even though agricultural surveys consider that land to be already 'potentially fertile'.

Irrigation in the province of Arequipa

	Thousands of hectares	*S/. (soles; i.e. Peruvian currency)*
Irrigation of the Majes and Siguas pampas area	90·0	1,394,641,191.00
Irrigation of the Cuno-Cuno .	22·0	441,884,734.30
Irrigation of the Arma River area	28·5	391,000,000.00
Extension of the irrigation of the La Joya pampas . . .	13·0	211,466,387.27
Total of the latter three schemes.	63·5	1,044,351,121.57

From the agricultural point of view and from the standpoint of the economy of the area, all these irrigation schemes are likely to produce similar results. According to the source referred to above, the Majes and Siguas pampas would be under alfalfa, wheat and fruit, in eight-year rotations and in the proportions of 56, 33 and 11 per cent. respectively. The irrigated land in the Cuno-Cuno area would be principally under alfalfa, wheat, other arable crops and fruit, that in the Arma River area under alfalfa, wheat and other arable crops—i.e. the same crops which predominate on the already irrigated pampas of the La Joya area. There is no reason to suppose that on the newly irrigated areas there would be a change in the type of crops grown. These irrigation works would have an obvious value from the point of view of the country's economy, since the production of feeding-stuffs for beef cattle and of wheat would make it possible to reduce imports of two important items which today require considerable expenditure of foreign currency.

Comparing the two types of scheme from the agricultural point of view and from the standpoint of the economy of the area and of the national economy, it is clear, at least as far as the cases under consideration are concerned, that large irrigation schemes have the following three advantages over small schemes:

1. lower cost per unit of area irrigated;
2. larger areas made cultivable; and
3. higher output and, therefore, saving of foreign currency resources.

Furthermore, the larger schemes make it possible to settle a larger number of families. This is an advantage from the social point of

view, particularly in an area of great demographic pressure where cultivable land is scarce.

These conclusions, however, are based on the assumption that the quality of soil and of productivity is similar. If the quality of the land in the three minor schemes were superior to that in the Majes and Siguas area, it is possible that they would be more economic and might permit greater density of settlement. There are no detailed agricultural or economic studies (at least, none are known to the author) which would permit an exact and more soundly based comparison of the benefits to be derived from investment in different types of irrigation works.

Let us now compare two of the three smaller groups of schemes in Arequipa with a large irrigation scheme in the north of the country, that of the Quiroz River in the Piura Province. This is already in operation and precise costs are known. It irrigates 45,000 hectares (111,201 acres) and has required an investment of S/.150 million (gold), plus U.S. $18 million, making a total, at the rate of exchange at the time, of S/.615,300,000.00 and a unit cost of S/.13,673.33 per hectare, equivalent to less than £77 sterling an acre—considerably less than the most economic scheme considered above, that of the Arma River.

The irrigation schemes of the Cuno-Cuno area and of the Arma River jointly would make it possible to bring a total of 50,500 hectares (124,793 acres) into cultivation at a cost (1956) of S/.832,883,734.00—i.e. £126 sterling an acre. The irrigation schemes of the Arma River and La Joya together would make it possible to bring 41,500 hectares (102,553 acres) into cultivation at a cost of S/.602,446,387.27—i.e. £111 sterling an acre. The Cuno-Cuno and La Joya schemes alone would make it possible to bring 35,000 hectares (86,490 acres) under cultivation at a cost of S/.653,350,121.57,—i.e. £142 sterling an acre.

It will be seen that the combination of the Cuno-Cuno and Arma River schemes would make it possible to bring 12·22 per cent. more land under cultivation at a 63·63 per cent. higher unit cost than the Quiroz River scheme; that the combination of the Arma River and La Joya schemes would bring 7·78 per cent. less land under cultivation at a unit cost 44·15 per cent. higher, and that, lastly, the Cuno-Cuno–La Joya combination which is 22·22 per cent. smaller in area has a unit cost 84·41 per cent. higher.

With regard to type of crop, it is estimated that in the Quiroz scheme, in addition to putting 12,000 hectares (30,000 acres) under pasture,

5,000 hectares (12,000 acres) under fruit-trees and 8,000 hectares (20,000 acres) under various food crops, 20,000 hectares (50,000 acres) might be put under cotton of the Pima variety which is much more rewarding economically than wheat, the principal crop in the Arequipa scheme. It is obvious that, economically speaking, the irrigation of the Quiroz area is more satisfactory than that of any of the smaller irrigation schemes of the Arequipa area.

From the social point of view also the results would be more satisfactory, since cotton production would make smaller holdings possible for a given economic return, provided that the size of holdings was governed by social considerations and that it was attempted to settle farm families (whose standard of living would rise) on family farms, leaving aside, or leaving at a low percentage, the larger holdings. In other words, if the creation of holdings in the Quiroz and Arequipa areas were based on social criteria, the former would make it possible to settle a larger number of agriculturists, which is an obvious social advantage.

Furthermore, the transformation into cultivated land—although agricultural conditions in the Quiroz area are not the best—will be more rapid since most of the irrigated land has been under natural pasture or shrubs, suggesting that there is a higher nitrogen content in the soil and a certain humidity in the subsoil.

Bearing in mind the necessary reservations it is clear in these cases that large-scale irrigation yields the better results from both social and economic points of view.