But it is the duty of the Government to teach the value of irrigation, and lay out a comprehensive system, and enforce proper laws on the subject.

CHAPTER IV.

History, description, and statistics of irrigation in foreign countries.

Introductory remarks: Authorities--Irrigation in India; its necessity--Famines--Extent of proposed works--Price of labor--Description of Ganges Canal--Other canals in the Punjab and in the northwest provinces--Delta-systems of Southern India--Other canals in India--Tanks; their numbers and dimensions--Mudduk Masoor tank--Mode of construction --Inundation-canals--Wells--Superiority of channel-irrigation--Improvements by the English--Silt--Velocity of canals--Drainage; its relation to health--Measuring water; its necessity in California--Navigation of canals--Primary ditches--Administration of canals in India.

Statistics: Of Western Jumna Canal--Of Bari Doab Canal--Of other irrigation-canals in the Punjab--Of inundation-canals from the Sutlej and Indus Rivers--Of the Ganges Canal--Of Eastern Jumna Canal--Of Dhoon Canals.

General remarks: Financial aspect--Cost of maintenance; of repairs.

Description and statistics: Of Delta-irrigation in Madras--The Cauvery Delta--The Kistna Delta--The Godavery Delta--Official report for 1873 --Financial statement--Prospects for the next five years--Private enterprises in India--Madras Irrigation Company; its agreement; embarassments--The East India Irrigation Company; agreement; failure --Opinions of governor-general of India and of home office.

In the rainless regions of Egypt and in some portions of India, irrigation and systematic agriculture are of the same age, the latter being quite impossible separate from the former. The present purpose does not require an inquiry into the date of its origin and the circumstances attending the introduction of irrigation in ancient times. It is sufficient on this point for us to know that it has been used for thousands of years, and that in some countries it has been continuously applied throughout their historic existence. The wide distribution and range of this mode of cultivation under the most diverse climatic conditions deserves to be referred to.

This range is almost as long and as wide as that of civilization itself. It embraces countries where the rain-fall is high and the mean temperature that of the temperate zone, and others where the temperature

is tropical and the rain-fall small or very unequally distributed. Within its limits are included England, France, Spain and Italy, Egypt and India, Java and the neighboring islands, the West India and the Sandwich Islands, Mexico and Peru. Even in our own country, irrigation exists in the river-cultivation of the South and on a small scale in our acquired territory where it was introduced by the Spaniards, who, in their turn, derived it from the Moors. The vestiges of works found in Arizona and Mexico point to a time when this mode of cultivation existed to a much greater degree than it does at present, and when perhaps the rain-fall was in excess of its present amount. It is also practiced to some extent in Utah.

In an investigation looking to the extensive introduction of irrigation into our imperfectly-watered plains, it is essential to inquire into the circumstances of its existence in other countries, in order to ascertain the proper principles of construction and of administration as they appear to have been established by the experience of other nations. The literature of irrigation is extensive, and the occasion is such that one might easily be tempted to collate historical and descriptive information, all interesting enough, on a scale that might defeat or interfere with the practical ends in view. It will be sufficient to give our attention chiefly to the modern phases of the subject, and to examine the conditions existing in countries whose civilization corresponds in some degree to our own; to ascertain the principles of administration; and to refer to those countries where it has long been established, or where it is being most widely extended, to learn its effects and its methods.

It is, then, the object of this chapter to take a cursory view of irrigation as it exists in some of the countries where it has long been established; to ascertain whether its influence is or has been favorable upon the prosperity, manners, and health of the people; to learn how works of this kind are provided and managed; to inquire into their financial condition, the cost of construction and of maintenance; and, generally, to inform ourselves as to what other nations have done or are now doing to introduce or extend this system of cultivation.

It may be remarked here that a sound financial basis is essential for the existence of irrigation; and if this basis be wanting, we ought not to permit the judgment to be carried away by beautiful pictures of trees and flowers and growing crops; these have in some cases been purchased at too dear a price. Irrigation may be desirable, but indiscriminate irrigation may be disastrous. The same conditions of care and prudence and judgment apply to this as to all other industrial enterprises.

Some of our points of inquiry could be better studied on the fields of practice than from the descriptions in books; but under existing circumstances we are compelled to draw our information from the researches of others. Fortunately, we have descriptions of most of the existing systems from the hands of intelligent observers, and, if we find diversity of opinions and inequality of mental vision when directed to the same circumstances, we only repeat a common experience. Irrigation has its panegyrists and its depreciators. The truth will most probably be found to lie between--in the middle way.

The principal authorities for what follows are these, namely: Col. Baird Smith, Irrigation in the Madras Provinces; Col. Baird Smith, Italian Irrigation; Lieut. Moncrieff, Irrigation in Southern Europe; M. Aymard, Irrigation du midi de l'Espagne; I. B. Roberts, Irrigation in Spain; papers and discussions by various civil engineers in England, published in Proceedings of Institution of Civil Engineers; various parliamentary and official reports in regard to Indian irrigation from 1848 to 1872.

IRRIGATION IN INDIA.

India affords us the most conspicuous examples of irrigation on a grand scale, and it is here more than anywhere else in the world that a great systematic scheme is in progress of development. Irrigation in some other countries is merely an incident. It permits the cultivation of certain crops, which, indeed, add greatly to general and individual wealth, and if it were withdrawn the general prosperity would doubtless suffer, but the basis of future existence would remain. In many parts of India, irrigation is the very condition of existence, both of the government and of the people. More than half of the revenue of India comes directly from the products of the soil; and the country is so vast, and the communications have been so difficult, that a generally good harvest has not sufficed to preserve large districts no so favored from the most dreadful ravages of famine. The failure of the northeast monsoon in 1832 caused in the Madras presidency most severe and extended suffering; and in Guntoor, out of a population of 500,000, it is estimated that 200,000 persons died of famine and of the fevers resulting from scarcity of food. More recently, in Orissa, a severe famine, causing a great loss of life, occurred, (said to be 1,000,000 persons;) and now in Bengal a similar disaster is impending.[29]

Hence, for double reasons, both for humanity and for the sake of its own revenue, the government is impelled to provide a remedy for these terrible evils. This remedy is irrigation, which is indispensable to insure a crop of rice, the main staple of food among the people. Under the influence of these powerful motives, the government has been, for some years, and is now, actively engaged in building canals and in extending irrigation on a scale that certainly appears, at first glance, large but which, in comparison with the work to be done, is no more than reasonable. The works that are now in course of construction and that are now projected, it is estimated, will cost $175,000,000, and the rate of expenditure is now many millions of dollars each year. When we attempt to realize the possible results of so great expenditure, it is important to notice that prices of labor and of most materials are very much below those ruling in our own country. The wages of a skilled laborer are 50 cents per day, and of an ordinary laborer 12 cents per day. Earth-excavation may be done for 5 cents per cubic yard, and masonry from $1.50 to $3 per yard. On the other hand, it is well to remark that the constructions are of the most permanent character, and of a much more expensive kind than we would be likely to adopt in our western plains.

The great extent of the country, its topographical features, its enormous population, and the volume of its large rivers, permit and require canals of length and section surpassing beyond all comparison any to be found elsewhere, unless it be in the single instance of the Imperial Canal in China.

The Ganges Canal is, indeed, an artificial river. It is intended to carry nearly 7,000 cubic feet of water per second. Its depth is 10 feet, and its width 170 feet in its upper part. Including its principal branches, it is nine hundred miles in length, and it is intended to irrigate 1,500,000 acres of land, an extent equal to that watered by the whole system of canals in Lombardy and Piedmont. Its length much exceeds the aggregate of the irrigation-lines in Lombardy and Egypt combined. It is the unrivaled instance of modern times. Its original capital cost was about $12,000,000, not including interest or other charges. In the United States the same work would cost $100,000,000.

The Ganges Canal is arranged for navigation as well as for irrigation. This circumstance, and others, relating to the difficulties of the country, and to its populous condition, which rendered necessary a great number of bridges, account for its cost, which, with the low prices ruling in India, is, however, regarded as excessive. Its aqueducts and embankments are necessarily on a very large scale, and it presents many points of interesting study in an engineering point of view. Some of these are the proper slope of the bed, which at first was, and, although improved, is still too great; the means for reducing this slope by overfalls; and the different arrangements to effect the result.

We learn from its history the prime necessity of giving the proper velocity to the water, and of the disastrous results that may follow from the velocity being too great or too small. Reference will be made to this point again in the statistics of the canal.

This canal is purely the work of the English; it was projected and built by the government.

The other canals of importance in the northwest provinces and of the Punjab are the Eastern Jumna, the Western Jumna, and the Bari Doab Canals, carrying from two to three thousand cubic feet of water per second, and each several hundred miles in length.[30]

Passing from Northern to Southern India, we find in the deltas of the Cauvery, the Godavery, and the Kistna Rivers, a comprehensive system of canals, no one of which, indeed, can compare in length or in dimensions with those just named, but which, taken together, irrigate large areas in their respective deltas.

The map of the Cauvery Delta, herewith attached, will illustrate better than a verbal description the arrangement of the canals and the system of irrigation. These delta-systems were not the earliest of the works restored and extended by the English, but they have been the most successful. They have enriched people and state alike. They have placed declining districts in a condition of the highest prosperity, and they have produced this result in a remarkably short time.

The slow development of irrigation, so noticeable generally on other canals, is wanting here.

The flowing water was in demand and was brought into use at once. The reasons for this remarkable success were the facts that the people were familiar with irrigation, and that from the conditions of the climate there could be no successful cultivation without irrigation, and, further, that by a conjuction of fortunate circumstances the works were very cheaply provided.

These systems form the staple of the argument for the extension of this mode of cultivation in other parts of the country.

The limits of this meagre review of the Indian system will permit us only to refer by name to some of the other important canals recently completed or in course of construction. These are the Soonsekala and Bellairy Canals from the Toombuddra River, three hundred and fifty miles long; the Saone,[31] just completed, from the river of the same name, to carry 4,500 cubic feet per second, with a capacity to irrigate about 1,000,000 acres; the Sirhind Canal, from the Sutlej River,[32] to cost $15,000,000; the Lower Ganges Canal, to carry 6,000 cubic feet per second; the Orissa Canal,[33] built by the East India Irrigation Company, all of which are very large enterprises, some of them rivaling the Ganges Canal in magnitude and importance. We may add to these the Agra Canal from the Jumna, and the Eastern Ganges Canal. There are other new works and extensions of existing systems to which it is not necessary to allude by name.

The government has built or restored, or is in the act of building, all of these canals but two, and it now owns all except one.

The history of private enterprise in this connection will be given elsewhere. Its efforts thus far have been unsuccessful, and there seems to be no prospect that it desires or that it will be permitted to undertake any further enterprise of this character.

This for the present may end our sketch of the channel-system, and we may pass to the notice of another conspicuous feature in Indian agriculture, namely, irrigation from tanks, or, to use our own more familiar term, from reservoirs.

One cannot restrain surprise when he first looks upon a map of the Madras provinces, and notices the number and distribution of these tanks. They appear to occupy nearly as much land as remains to be cultivated. In fourteen districts of the Madras presidency, the English found, in better or worse condition of preservation, fifty-three thousand tanks, estimated by Col. Baird Smith to have 30,000 miles of embankment and 300,000 separate masonry works, consisting of sluices and waste-weirs. These tanks afford a revenue of $7,500,000. How many more there are in India it is probable no one knows. We do know that the numbers above given are found in a relatively small area.

These tanks are, it is believed, all, or nearly all, of native origin, and the dates of their construction remain in uncertainty. It is known that some have been in existence for many hundred years.

The English have repaired many of these works, but so far as is known they have not built them, at least to any great extent.

Recently there have been plans for building new or restoring old tanks on a large scale.

Tanks are necessary adjuncts to a system of irrigation which aspires to use a very large portion of the water in a country where heavy freshets prevail, or where the rains fall in a short interval, for they store the surplus waters.

In size tanks vary greatly. The Ponairy tank in Trichinipoly[34] had an embankment of thirty miles in length and a storage-area of about seventy square miles. The Veevanum tank, which is shown on the map of the Cauvery Delta, has an embankment of twelve miles in length and an area of over thirty square miles.

A reference to the details of the Mudduk Masoor tank on the river Choardy may serve to give us some sort of conception of the labors undertaken by the natives four hundred years ago to secure a supply of water for cultivation.

It is interesting, too, in an engineering point of view, to notice the height of the dam; for it has been claimed by high authority that it is impossible to build safely earthen dams approaching this one in height.

The dam, or *bund*, as it is called in India, bridges a narrow gorge, its extremities resting on high mountains on either side. Its length on top is 550 yards. Its interior slope varies from 2 1/2 to 3 base for 1 in altitude. This slope was revetted with large stones laid dry. The greatest height of the dam is 108 feet and the base in its broadest part is 1,100 feet; it is made of red earth containing considerable gravel. It possessed no waste-weir, and this fact is supposed to account for its ruin. The depth of water in the tank is believed to have been from 90 to 95 feet, which would give a storage-area of forty square miles, and contents of 1,400,000,000 cubic yards of water. Its drainage-basin is about five hundred square miles.

Most of these tanks are, of course, not nearly so large, and those on the plains are generally shallow, having a depth of 6 feet and up to 10 feet. They were generally placed where the accidents of the ground favored an economical storage. In some cases they were supplied directly from the natural drainage; in other cases they were filled by artificial channels which brought to them the flood-waters of the rivers to be stored for times of need.

The dam is usually of earth and built in the native way, that is, the earth was carried in baskets and distributed in layers of 6 to 8 inches in thickness, which were packed by the feet of the carriers passing to and fro; no clay puddling was used, the silt, carried by the infiltrating water, serving to render the dam finally water-tight. They were provided with masonry sluices to deliver water into the channels which irrigated the land below.

The interior slope was usually revetted with stones. They were generally provided with masonry waste-weirs, which stopped several feet short of the height of the earthen dam. In the crest of the weir were placed stone posts 4 or 5 feet high, which permitted the easy construction of a light dam of brush or straw to hold the water up as high as possible. If a flood came, this temporary dam, when not previously removed, gave way easily and the flood-water took its course over the weir.

From various causes, their numbers are becoming less; some are filled by silt; others are breached from want of attention and repair.

The extension of the channel-system through the tank-districts supersedes the tank-irrigation by degrees.

The fertilizing silt, brought from the mountains, gives the running water a value superior to that stored in tanks, where the matter in suspension is deposited. On the other hand, by reason of this deposit in tank-beds, they are classed, where dry, as among the most fertile lands of India.

A map of a small district in the Madras presidency is attached which may serve to give some conception of the numbers and average areas of these reservoirs.

Among the irrigation-facilities not yet noticed are what are termed inundation-canals. These differ from the class first noticed, which may, with some allowance, be called perennial, in the fact that they only carry water from the rivers in seasons of high freshets. The beds are on a higher level than those of the perennial canals. The season of freshets is so unequal, and the supply of water is so precarious, that irrigation by inundation-canals becomes peculiarly uncertain, even when the water carried by them is stored in reservoirs. The irrigation in Egypt is of this character.

These canals are of native origin. As a rule, they have no headworks, and they are peculiarly liable to injury from breaches, by floods, and by silt deposit.

Some of the principal canals of this character are taken from the Indus and the Sutlej Rivers.

Wells afford another source of supply, from which an unknown acreage of very large extent is watered. These wells are generally square pits lined with masonry, from a few feet to 60 feet in depth, and from each three to ten acres are irrigated.

The details of the raising and distribution of the water are very curious and interesting, but for our purposes we may dismiss them with the remark that they indicate a patient, painstaking population of which the people of our own western country afford few examples. This system may impress us with the value of water, but otherwise it has no lesson for us.

The water in these wells rises to a higher level where the canal passes near them, a fact which may be noticed in California.

The cost of irrigation from wells in some cases is stated to be as much as $7.50 per acre each season.

The canals afford better water so much more cheaply that the well-supply loses its importance. The change to channel irrigation is, however, slow, as the history of the various canals hereafter to be alluded to will show.

This completes the outline of the modes of irrigation-supply existing in India. We do not find any statement of land irrigated nor of the relative proportions irrigated from the various sources. Nor is it important that we should be able to state this amount with even an approach to accuracy.

The main conclusions are plain that canal-irrigation is considered to be the most economical and the most valuable, and that every effort is made to replace the old methods by the new, and that as yet the work has only been begun.

British India contains 800,000 square miles and a population of 200,000,000, and but a small proportion of the land is yet under this mode of cultivation.

The English appear as restorers and promoters of irrigation, and not as its originators.

The service they render is to place the system under sound principles of construction. The native system, like all the earlier systems of the world, was defective in alignment and expensive in repairs.

The English are introducing proper slopes and proper velocities, and are making the arrangements permanent, where before they were temporary. The construction of permanent dams in the sandy beds of the rivers was beyond the native skill. They were compelled to rely upon temporary structures, generally banks of sand, which were swept away by the annually recurring floods. To protect the canals from the destructive action of floods, the natives closed the head by a temporary bank, to be removed when the flood had passed. The English have provided permanent head-works, arranged with sluices, by which the floods may be controlled. The drainage, which was little considered by the natives and which yet remains in need of correction in some places, is now attended to, and regulations are provided to guard against the sanitary evils which follow upon the presence of stagnant pools in hot countries.

Silt is a formidable enemy in India. The rivers in floods come down laden with particles of soil in suspension. The Ganges in flood has in suspension one fifteen-hundredth of its bulk. The Ganges Canal, flowing 6,000 cubic feet, therefore receives for a time 4 cubic feet a second, or nearly 13,000 cubic yards of silt in a day.

The great problem is to dispose of these large quantities. When the velocity is slackened, as it must be in a canal, for generally the banks and beds cannot sustain so great a velocity as the river maintains, the silt begins to make deposits. Then, again, if the silt is of a fertilizing character, it is very desirable to transport it in suspension to the irrigated land to assure its fertility.

Again, the water of the river in its lower stages may contain very little silt, and a velocity which silt-laden water may carry with safety through earthen beds and slopes becomes under the changed condition erosive and produces great injury. So the conditions may contradict themselves, as, indeed, they actually do in the Ganges Canal.

The question of the proper velocity to be given may thus not admit of positive solution in some cases; but when the solution is possible, its importance cannot be overestimated. Upon this point may hinge the success or failure of the canal.

If the velocity be too great, it may involve heavy expenditures for repairs, which finally may become so burdensome that the canal has to be lined with masonry, as is the case on the canal of Caluso and others in Italy; or, if the velocity be too low, the canal-section has to be increased to carry the requisite quantity of water, thus entailing increased expense, and perhaps the canal must be closed once or twice a year for clearance, at a large outlay.

The canals in India show great differences in the cost of repairs.

In some cases the canal-section at its head for a mile or so is made wider than the general section to insure the deposit in this part, so that when clearance has to be made it is done at one place rather than all along the line. Then, too, the river at the head of the canal may silt up to the level of the crest of the dam, and the canal-supply may thus be cut off. This is generally provided for by placing a number of sluices in the dam or adjoining it, so arranged as to scour out a channel above and leave the canal-head clear.

For clearance of flood-water in the canal, waste weirs are sometimes placed in its banks connecting with natural channels, which shall carry off the surplus water.

DRAINAGE.

Standing pools of water as connected with irrigation are, of course, the result of defective drainage, but they may be produced in different ways or proceed from different causes. In India these cases occur when an embankment is carried across a natural channel, leaving no exit for the water collected above. Such a construction, it is plain, endangers the safety of the canal. Again, there is leakage through the pervious beds and banks, and when the canal is carried 20 or 30 feet above the ground, as is the case in the Ganges Canal, this leakage may be considerable.

Another source is careless practice in distributing the water, and in not providing for its escape after it has done its duty. There is plain loss to the canal in all of these cases, and, worse than this, the sanitary condition of the neighborhood becomes unfavorable.

The rice-cultivation, which, in a certain sense, involves the opposite of drainage, is too well known to be productive of miasmatic diseases, in all parts of the world, to deserve more than a reference here.

We know what to expect of rice-fields, but there is danger that wheat-fields may prove no mean rivals of rice-fields in unhealthfulness. It costs money to secure good drainage; and if this fact is no reason why there ought not to be good drainage, it certainly accounts, in common with ignorance, for its absence in many cases.

It has been thought by many that the introduction of a system of selling water by the cubic foot instead of making a definite charge per acre irrigated would, by making it to the interest of the cultivator to use the water economically, put an end both to waste and to part of the evils of bad drainage.

The same crop on different soils requires different quantities of water, while there is equal variety in the amount required by different crops on the same soil. This latter difference is recognized in India, the charges depending on the character of the crop; the sugar-cane, for instance, pays about $3, while cereals pay about one-fourth as much, but no discrimination is made either for the receptiveness of the soil or for care and economy on the part of the irrigator.

It certainly seems to be a reasonable proposition that water should be sold, as all other articles of commerce are sold, by measure; but the difficulties attending its measurement under different and ever-varying heads, and through varying dimensions and shapes of outlets, and more than

this, the ignorance and suspicious character of the cultivators, have thus far been able to defeat the establishment of such a system.

It may well be considered whether such a system ought not to be ingrafted upon the irrigation of California in its infancy, where the people are in some degree familiar with the measurement of water by the miner's inch, and where their superior intelligence ought to be equal to the comprehension of its justice, and of the favorable sanitary results it promises to secure. If, however, this mode of measurement cannot be established at once, we may be doubtful of its later success.

The new canals in India generally combine navigation with irrigation. It may be remarked that in the abstract those objects conflict. The irrigation-canal ought to carry water at a high velocity, as high as its bed and banks will permit. The navigation-canal ought to have little or no velocity. Where the soil is light, the velocity of the irrigation-canals may of necessity be so low as to permit navigation at little or no additional expense. The case is one to be determined by attendant circumstances of facility of communication and expense, and no absolute rule can be laid down.

A canal from Tulare Lake, for instance, to irrigate the west side of the valley, would necessarily have a low grade in order to insure a command over the maximum quantity of land. The velocity would be small, and navigation would be practicable as well as desirable.

PRIMARY DITCHES.

It is important for the success of the canal that the primary ditches should be laid out on the proper lines. This line may not be the one desired by any particular cultivator. The considerations that should govern its location are mainly topographical and general.

To insure a good location and an economical distribution of the water, it seems essential that the owners of the canal should mark them out even if they do not build them.

It is also regarded as conducive to economy and good drainage that irrigation should not be allowed directly from the canal, but only from the primary or secondary ditches.

It is to other countries more nearly assimilated to our own institutions and modes of civilization than is India that we must look for an administration-system that shall fit our condition, if, indeed, any such system can be found. In India, the government does everything and the people do nothing in the management of the canal-system. On the other hand, in our country we expect the people to do everything and the Government nothing. There, all power and authority are in the hands of the officials, whose range extends to the merest details. This state of affairs is much lamented by intelligent observers, but in the present condition of the people any other system is impossible. We shall find in Italy and Spain that the principles of self-administration, and, in some degree, of self-government, have existed in irrigation-associations for years, and in some cases for ages.

Americans will doubtless find in this kind of administration something congenial with their opinions, and perhaps they may discover in it the germ of their own modified system of the future.

We may terminate this review of Indian systems with the following observations from the pen of an intelligent observer and critic, well informed in the history and experience of irrigation:

> Statistical details and magisterial experience show clearly that where irrigation, with its pleasant train of consequences, is introduced, crime diminishes, plenty and security prove the best policemen, lawless habits yield to their genial influences, and men who were the Ishmaelites of society fall without force or constraint into the ranks of the great army of industry.

STATISTICS OF CANALS IN INDIA.

CANALS IN THE PUNJAB.

Western Jumna Canal.

This canal was built in the fourteenth century by the Mogul Emperor and was restored by the English about 1820. In 1871 the capital account stood at $1,381,000, leaving out the interest and charges which had accumulated against the enterprise during the years when its receipts did not defray its expenses. It required fourteen years to work up to its expenses. It irrigated, in 1871, 444,385 acres; the capital cost per acre being something over $3. Its length is over four hundred miles. It carries from 1,800 to 2,200 cubic feet of water per second. The maximum water-rate per acre is $2.50; the minimum 67 cents, the average being $1.22 per acre. The cost of maintenance in 1871 was 46 cents per acre. The profit for the year was 26 per cent. The government reaps additional profit from increased tax on lands. The principal crops are sugar, rice, cotton, and wheat. One cubic foot per second irrigates in the summer 102 acres and in the winter 114, making a total of 216 acres. The rain-fall near head of canal in 1871 was 70 inches and at the lower end about 11 inches.

The Bari Doab Canal.

This canal was built by the English, and opened about 1860. To 1871 it had cost $6,297,600, to which should be added for interest and deficit, in paying expenses, $1,388,672, making a total cost of $7,686,272. It irrigated, in 1871, 287,070 acres. The canal has carried 2,300 cubic feet per second, but in low water it may come to 1,300 feet, and has capacity to irrigate about 500,000 acres. When it attains this extent of irrigation, the capital cost per acre will be about $15; the maximum charge for water per acre, $2.94; the minimum charge for water per acre, 75 cents; the average gross income per acre irrigated, $1.17; cost of maintenance, 65 cents per acre, being 56 per cent profit on original capital in 1871; and

in 1872, 2.68 per cent., and, including land-tax, 4 2/3 per cent., which rates are the same for the next preceding year; repairs of principal distributing-ditches about $8 per acre. It irrigates in hot weather 41 acres per foot a second; in cold weather, 111 acres per foot a second; total, 152 acres.

OTHER IRRIGATION-WORKS IN THE PUNJAB.

Delhi and Gargaon Works.

These works have cost $92,000, and they irrigated in 1871 about 8,000 acres. They were worked at a loss of over $3,000, and in the previous year the loss was about $7,000. If the enhancement of the land-revenue be included, the profit is said to be about 10 per cent.

Lower Sutlej and Chenab Inundation Canals.

These are old Mohammedan works, which carry water only during the prevalence of freshets. The period of freshet fluctuates very much, and irrigation is peculiarly uncertain. Capital expended, $56,000. Expenses exceed direct revenue to the extent of 33 per cent. of capital; acres irrigated, 188,000.

Upper Sutlej Canals.

These canals are of the same character as those last mentioned. They have cost $282,000. Deficit, 1871 and 1872, $50,000, 16 per cent. of capital; 87,000 acres irrigated. These inundation-canals in all are six hundred and fifty miles in length. The repairs upon them are enormous. In the last year 2,300,000 cubic yards of silt had to be taken from them.

Indus Inundation-Canals.

These are old native works over five hundred miles in length; cost, $192,569; loss in 1871 and 1872 about $50,000, over 25 per cent. of capital; loss previous year, 6 per cent; irrigate 144,000 acres.

CANALS IN THE NORTHWEST PROVINCES.

The Ganges Canal.

This canal was begun in 1842 and opened in 1856. In the year 1860-'61 it first paid its expenses; 1862-'63, deficit of $50,000; 1863-'64, paid 1 per cent. profit; 1864-'65, paid less than 1 per cent.; 1865-'66, paid 2.83 per cent.; 1866-'67, paid 3 1/2 per cent.; 1867-'68, paid 2.44 per cent.; 1868-'69, paid 7.29 per cent.; 1869-'70, paid 4.69 per cent. At the end of 1870 this canal had cost $12,038,305. The deficit of revenue and

the interest on the capital had accumulated a further charge, variously stated, the minimum being $4,000,000, the maximum more than $5,000,000. This added makes the cost of the canal in 1871 from 16,000,000 to $17,000,000, and as the profits above given are calculated only on the paid-up capital, the rates should be diminished in a corresponding ratio.

Progress of irrigation.

In 1861-'62, irrigated 372,322 acres; 1862-'63, irrigated 205,605 acres; 1863-'64, irrigated 449,788 acres; 1864-'65, irrigated 566,517 acres; 1865-'66, irrigated 573,129 acres; 1866-'67, irrigated 634,734 acres; 1868-'69, irrigated 1,441,918 acres; 1869-'70, irrigated 1,089,673 acres.

Sugar-cane, $2.20 per acre; 12 per cent. of land pays this rate. Gardens, rice, $1.25 per acre; 20 per cent. of land pays this rate. Indigo, cotton, &c., 80 cents per acre; 51 per cent. of land pays this rate.

Grains, 60 cents per acre; 17 per cent. of land pays this rate.

Giving mean rate of $1.02 per acre.

In 1866 and 1867 average gross revenue per acre irrigated, $1.21; cost of maintenance per acre, 50 per cent., or 61 cents. It required ten years for this canal to reach 30 per cent. of its probable ultimate irrigation. The Eastern Jumna, which now pays a handsome profit, took thirty years to reach the same condition.

EASTERN JUMNA CANAL.

This is a canal taken from the river Jumna. It was an old native work, which had fallen out of repair, and it was restored by the English and opened in January, 1830. It did not pay its expenses until the year 1838; the deficit up to that time being about $130,000. In 1839, 1841, and 1844 it ran largely behind its expenses. In 1845, 1846, and 1847 its income was insignificant; including 1847, and counting from its opening, it was behind its working expenses $141,000, to say nothing of interest on its capital cost and of previous deficits. In 1856 it was again behind $20,000. In 1857 and 1858 deficit were $3,230, and it was not until 1865 that its profits caught up with charges of interest and maintenance. In 1867 its capital was $876,030, and it irrigated 239,555 acres. The capital cost was at this time $3.70 per acre. It paid this year a revenue of 25 per cent., and the state was further benefited, indirectly, by increase of land-assessment. The average income per acre irrigated was $1.12; cost of maintenance, 25 cents, being 22 per cent.

DHOON CANALS.

Capital expended to end of 1865, $266,850. Worked at a loss ever since 1841. Accumulation of charges and interest to 1865, $129,770. In 1866 and 1867 Dhoon paid a profit of 2 3/4 per cent. on original capital, and irrigated 8,852 acres. *Capital* cost per acre irrigated, about $30.

The Rohilcund Canals[35] irrigate about 100,000 acres; in some years, often very much less. The cost of these canals, without interest, is about $170,000. They have generally been worked at a loss. The water-tax is only about 25 cents per acre.

Agra Irrigation Works[36] cost over $100,000, and have in some years not paid their expenses, while in other years they have returned an insignificant income. Since 1864 they have been closed for sanitary reasons.

GENERAL REMARKS.

The canals and irrigation works in the northwest provinces, comprising Ganges, Eastern Jumna, Dhoon, and minor works, had cost, at the end of 1869, $13,503,525; add interest and charges, $4,589,000, giving a total of $18,092,525; net revenue 1869-'70, $683,515, being about 5 per cent. on the capital alone, and less than 4 per cent., including capital, accumulated interest, and charges. If we include the enhanced land-tax due to irrigation, the revenue is considerably increased. The amount of increased tax to be estimated as due to irrigation cannot be ascertained with precision, but it is probably sufficient, when added to the direct revenue to make a fair return on the capital invested. Nevertheless, the financial aspect of these enterprises, taken as a whole, is not at present satisfactory. The slow development of irrigation is certainly a remarkable feature in their history; it is sufficient alone to ruin financially an enterprise of this character. No joint-stock company could exist on such a basis; none could be formed to build a canal which, when finished could not for five or ten years pay its expenses, and from which no profitable return could be expected for twenty or thirty years. Yet it deserves to be remarked that the value of these properties increases from year to year, and that the time must come when they will be very valuable. It may also be noticed that an enterprise of this kind may, be reason of increase in land-tax, be profitable to the government when it would be disastrous to a joint-stock company.

In India the government is really the landlord, a circumstance which makes the obligation of irrigating the country peculiarly strong, and which, at the same time, insures a share of profit which could not inure to a private company. The cost of maintenance of the canals when built and in full operation deserves to be remarked. This ranges from 56 per cent. of gross receipts on the Bari Doab, 50 per cent. on the Ganges, 37 per cent. on the Western Jumna, to 22 per cent. on the Eastern Jumna. In this item are included all expenses of salaries, of repairs, and of contingencies. It is the item of repairs which it is important to notice, for the repairs may alone eat up all the profits, as indeed they actually do in the inundation-canals of the Sutlej and Indus. The repairs on the Bari Doab Canal are 33 per cent. of the whole expense of maintenance, whereas they are but 15 per cent. on the Western Jumna.

In the Ganges Canal the expenses on this account have been enormous, amounting almost to a remodeling of the work. Both in the Bari Doab and the Ganges Canals these repairs are stated to be necessary, on account of the faulty original construction, owing to which great erosion of the beds

and banks occurs in some places and large deposits are made in other places. This is alluded to here merely to show that a correct adjustment of dimensions, slope, and mode of construction has a direct relation to the financial state of these enterprises.

CHANNEL-IRRIGATION IN THE DELTAS OF RIVERS IN THE MADRAS PROVINCES.

The works in the deltas of the Cauvery, Godavery, and the Kistna Rivers[37] have been the most remunerative in India; but some explanation of the circumstances attending the development of irrigation is necessary for even an incomplete comprehension of the case. Different authorities estimate returns from these works so variously that we may well despair of getting any clear knowledge.

First, in the Cauvery delta there have been irrigation-works from the dawn of history. A dam made of stones of moderate dimensions, set in clay, is still in existence, which has stood sixteen hundred years, and which is yet an important part of the system. Many channels were cut from the river-bank, which were supplied by the aid of temporary dams, and an extensive system of channel-irrigation has existed for ages.

The English came into possession of Tanjore in 1801, and about thirty years afterward attempts were made to correct some evils which had been growing in magnitude, and which affected the prosperity of the district and even threatened to destroy it.

The Cauvery River on entering the delta is divided into two channels, one called the Cauvery, and the other the Coleroon. From the Cauvery 505,000 acres of rice-land were irrigated, which required a supply of 12,600 cubic feet per second; while from the Coleroon 165,000 acres were watered, requiring 4,125 cubic feet per second. Now, the trouble was this, namely, that the Cauvery in 1833 could supply but 9,375 feet, while the Coleroon had 7,500 feet. The Coleroon had too much water, the Cauvery, too little, the gross amount, however, being equal to the duty required of both channels. Moreover, there was considerable danger that the whole river would go to the Coleroon, and leave the Cauvery district without water.

The English began to regulate the rivers, first, by building a dam across the Coleroon adjusted in height to give the Cauvery the needed increment of supply. After a time, the Cauvery, instead of not getting enough water, got too much, and there was danger that the whole river would go to the Cauvery, to the destruction of the lands depending on both streams. This danger was averted by a dam across the Cauvery, and after eight or ten years the engineers were able to control both rivers, and to distribute the water as was required. This was accomplished in 1845.

The whole story is very interesting and instructive, and it is well told by Col. Baird Smith.

The English, therefore, did not build the system of canals shown on the map of the Cauvery Delta. They, however, saved them from ruin, and improved them, and thereby assured the prosperity of the district. When, therefore, we hear of the profits of irrigation in this delta being so great, we should reflect that the profits paid are on the capital expended

to save, and in some cases to restore, old works, and not to build them. This district is termed the Lombardy of India.

Col. Baird Smith estimates the profits in 1853 to be 23 per cent.; others place them much higher. The fluctuations of the crops, which, before these operations, were as much as 50 per cent., have since been quite insignificant. In these provinces the government-tax is in the form of a percentage of the products. The rate in this district is two-fifths of the gross products, which includes land and water tax, and which certainly appears very high.

We cannot avoid having respect for the ancient rulers of India when we reflect upon the intelligence displayed in the arrangement of the system of canals in the Cauvery Delta.

The Kistna Delta.

The irrigation of the Kistna Delta was effected by the English, who were moved to undertake it by the terrible famine in Guntoor, already referred to. These works are comparatively recent, having been commenced in 1852. The profits are estimated at 15 per cent.

The Godavery Delta.

The Godavery Irrigation Works are intended to irrigate about 800,000 acres. They were constructed by the English, beginning in 1847; and in 1862 and 1863 the returns were estimated to be 47 per cent. on the capital expended.

It has already been stated that the circumstances of these delta-works were peculiarly favorable. The rivers run on the crest of the alluvial deposits they have themselves made, and their banks are from 6 to 20 feet above the land to be irrigated. This circumstance gives the canals command of the land at once. There were many old channels in these deltas, which were used to convey the water, which saved the construction of new works; and when new channels were needed they were easily excavated in the alluvial soil.

The delta-works on these three rivers, in all, irrigate about 1,500,000 acres of land. The cultivation is generally in rice, 40 acres of which require a cubic foot per second. The quantity of water used would be sufficient to irrigate fully five times as much land in cereals.

Among the projects sanctioned by the government, which are now in course of execution, are large extensions of irrigation-works in each of these deltas.

From the official report of the government of India for 1873, which has just been received, we make the following extracts, showing the present financial condition of the irrigation-works as estimated from the "best information available:"

	Capital account to the end of 1871-'72.	Net income as per latest information.
Madras, (30 works only)	*$6,535,000	$1,835,000
Bombay, including Sindh	* 3,990,000	7,500
Bengal	10,815,000	** 112,500
Northwestern provinces	16,655,000	@ 830,000
Punjab	11,300,000	@@940,000
Sindh	* 4,000,000	950,000
Total***	53,295,000	4,450,000

* Amounts not known; these are approximate sums.
** Loss. A capital of $10,000,000 in Bengal nets a loss of $112,500.
@ Includes increase of land-revenue due to the canals of $220,000.
@@ Includes increase of land-revenue due to the canals of $490,000.
*** Pounds sterling converted at $5.

This report states--

> That so far as existing information goes, the net results of the entire outlay on irrigation-works, up to the year 1872-'73, is a return of $2,068,200 per annum above the interest, at 4 per cent., on the first cost of the works.

We may remark, in regard to this claim, first, that the government is receiving a very large portion of this revenue from works which it never built, but to which it fell heir, and of which the cost does not enter the capital account; secondly, the deficits of working expenses on many of these works for years, and the interest on these deficits, are not included in these capital accounts.

In further considering the prospects of works of this character for six years in advance, the report states:

> No profits have been calculated from any of the new works within the period embraced in the forecast.
>
> It is found by experience that, as a rule, the growth of irrigation from new canals is slow, and in the first few years the canals hardly pay working expenses.
>
> The only source of increased income to be reckoned, therefore, is the growth of the returns from the canals already working.

It has been found from experience that returns continue to grow long after the works are apparently in full use.

This growth is largely due to increasing economy in the use and management of the water, which permits the cultivation of a larger area with the same amount of water.

The increase of net revenue for the next five years it is estimated will be $100,000 for each year.

The new works sanctioned by the government, which are now in progress, are estimated to cost $115,000,000, and the estimated yearly expenditure from loans on this account runs from $5,000,000 to $8,000,000 for the next six years.

Other works are contemplated, and are in course of survey and examination, which are not included in the statement given above.

It further appears from this report that the Ganges Canal irrigated in the last year but 684,139 acres; that its capital account is now $13,000,000; and that the direct returns for the past year were 2 1/3 per cent. on this expenditure; that the capital account of the Eastern Jumna Canal is now $1,030,000; that its acreage last year was 184,153, and its direct returns were 16 3/4 per cent. on the invested capital. These returns are less favorable than those which we have already given for the preceding year. No explanation for this difference is known to us, but it is probable that the rain-fall was more favorable to the cultivators than was the case in the two preceding years, and hence that there was not so great a necessity for irrigation.

A large portion of the cultivation in these districts is devoted to cereals, and in some seasons the rain-fall is such that these crops do not require irrigation.

The facts contained in this last official report add further evidence in support of the conclusions, resulting from our previous inquiry, and confirm the opinion that, except in particular and favorable instances, the irrigation-works of India are not such investments of capital as private companies would desire to make. It does not follow from this proposition that it is not good financial policy for the government to extend these works. The government has indirect sources of revenue depending upon the production of the country, which may more than make up for direct deficits. This, at least, is the opinion of the government of India.

PRIVATE CANALS IN INDIA.

Under the English supremacy, the native works of irrigation remained, as before, the property of the government, which undertook to keep them in repair, to administer them, and to receive their revenues. The results of irrigation have always appeared so favorable to the Indian government that it has endeavored in every way to extend their range and increase their facilities. In order to hasten the work, after very full discussion, it was decided to call in the aid of private capital. To this course there were many objections. It was generally held that the property in water could not safely be intrusted to private hands; that the ignorant cultivators would, without the intervention of the government, be helpless

against a powerful corporation; and that any supervision by the government, to be effectual in protecting the cultivators, would interfere with the freedom of the enterprise, and, therefore, with its prosperity and success. At this time it was thought by the government that the profits of irrigation were great and immediate, and that they should inure to the government and not to a corporation. On the other hand, the demands upon India for railways and other improvements were so great, and its resources so inadequate, that it appeared indispensable to call in private aid, if the development of irrigation was to be undertaken on an extensive scale. So it was determined to make the experiment of private irrigation; and in 1858 an agreement was entered into with the Madras Irrigation Company to build a canal, estimated to cost $5,000,000, and upon this sum the government guaranteed an income of 5 per cent. The system of guarantee had been the rule with the government for some years in constructing the lines of railways. The government was to divide all profits above 12 per cent. The other conditions of the agreement were substantially the same as those yet to be mentioned in the contract with the East India Irrigation Company for the construction of a canal in Orissa. The history of the Madras Company's enterprise is briefly this: The company raised and expended $5,000,000. They found that a considerable sum would yet be required to complete their works. They applied to the government for guarantee on an increase of capital. The government declined to grant further guarantee, and the company was unable to raise any more funds. The government under these circumstances felt obliged to give further assistance, which it did by lending the company $3,000,000, to be repaid from the profits of irrigation. In 1872 the government had paid $2,559,260 in interest, and had expended in all $5,559,260. The company had expended $5,000,000, making the total expenditure $10,559,260, to which should be added, for five years' interest on $3,000,000 at 5 per cent., $750,000; total cost, $11,309,260. The works were commenced in 1859 and completed in 1871. The prospect of immediate returns is quite unfavorable. The company expected to irrigate in 1872 at least 40,000 acres and perhaps as much as 100,000 acres. The rate is $3 per acre. The estimate by the government is not as favorable as that entertained by the company. It is worthy of remark that the system of guarantee of interest on the capital removes from the company a great motive for economy. The operations of this company have been considered extravagant, and the cost unnecessarily large.

THE EAST INDIA IRRIGATION COMPANY.

The Madras Company had hardly made a beginning before the East India Company undertook to build a canal in the delta country of Orissa under the following conditions: No guarantee of interest by the government; the government to give, free of charge, all land required for permanent works; when the works are completed, the company shall sell to the government all the water that irrigators shall desire to use; that the government shall distribute the water, and shall return to the company the net amount received from cultivators, full expenses of distribution and collection of water-rates to be deducted from gross receipts; the price of water shall be fixed by the government and the company, by arbitrators, two chosen by each party, and an umpire selected by the arbitrators in case they fail to

agree; the government to have the right to purchase for six months after the expiration of the twentieth, thirtieth, fortieth, and fiftieth years of occupation, paying the mean market-value of the stock in London for three years preceding purchase; the company shall keep their works in good repair, and if they fail so to do the government may make the necessary repairs, re-imbursing itself from the water-revenue; when the net profits exceed 25 per cent., the excess shall be equally shared by the company and the government; the works shall be executed under inspection of the government, and the company shall reconstruct any part not approved by the government.

It appears, from this statement, that the company builds the works and keeps them in order. The government acts as the agent of the company, and reserves to itself the right to protect the cultivators from inordinate charges on the part of the company.

The company proceeded under this contract to execute an extensive system of irrigation, but before long they fell into embarrassment, and were unable to raise the means to carry on the work. The government gave them assistance from time to time, and finally purchased the works from the company before they were completed.

The famine which occurred in Orissa during the progress of these works, by which many hundred thousand persons perished, demanded the speedy construction of the canal, and this added to a growing conviction, now become settled, that under the peculiar circumstances in India it was undesirable that irrigation-works should be intrusted to private parties, induced the government to make propositions of purchase to the company, which were accepted and the works passed out of its hands. This transfer leaves the Madras Company, before mentioned, the only private corporation engaged in selling water for irrigation, as least on a large scale.

All the principal works now in progress or that have been undertaken for the past ten years are in the hands of the government. Private enterprise, never heartily engaged in this kind of work, appears now to have been compelled to abandon the field. The opinions of the government are made clear by the following extracts, viz:

Minute by his excellency Sir William Denison, governor-general of India, January, 1864, and dispatch of the home government to the government of India, dated August 8, 1864.

These extracts give a fair statement of the views of all the government council of India, and it does not, therefore, seem necessary to quote further from the official correspondence on the subject.

Minute by his excellency Sir William Denison, governor-general of India.

> My experience of the working of the Irrigation Company in Madras justifies me in asserting that the system which has been adopted in dealing with this company is essentially faulty, and will lead to every kind of complication; disputes will arise, as indeed they have already arisen, as to

the value of the water, the mode of distribution, the quantity to be given per acre, whether the occupier of land under the level of the supply-channel is to be compelled to take water, &c., *ad infinitum.* I see no means of framing the clauses of a contract in such a manner as will reconcile the rights of the government as proprietor of the water, as landlord of the estate, and as protector of the rights of its subjects, with the claims of a company whose only object is to make as large a profit as it can upon the capital it expends.

In our anxiety a few years ago to introduce capital and to hasten the completion of certain works of acknowledged utility, we overlooked the difficulties which we were warned would arise out of the conjoint action of the government and the company in dealing with questions relating to assessment of land, I think our experience now is sufficient to justify a statement on our part that the system upon which we have dealt with the company is not likely to be to our advantage, and that we decline altogether to extend it beyond the projects which have already been undertaken and commenced, viz, that of the Madras Irrigation Company under a partial guarantee and the Orissa project; and I should propose to word this communication to the company in such a manner as to exclude any proposed extension of their undertakings under existing contracts.

There are two modes in which this or similar companies should be dealt with. They may act either as contractors for the execution of the works, in which case they would not be responsible for the plans; or, they may agree to carry out a given work for the supply of water to a given district, such water to be delivered at points determined by the government, and to be paid at a fixed price per 100 cubic yards, or for any selected amount of measurement; it will then be for the government to determine the quantity it can profitably employ at each issue from the canal, and to state the maximum it will pay for under any circumstances, and the minimum which the company must be bound to deliver. The company should have nothing to do with the profits of the application of the water.

Public works.--Dispatch from the secretary of state to the government of India, dated 8th August, (No. 39,) 1864.

* * * * * * * *

2. The plan of intrusting the execution of irrigation-works to the agency of private companies was, as you are aware, introduced in 1858 as an experiment. The arguments for and against the system were fully considered; and it was during the period of financial difficulties, when doubts were entertained of the government being able to raise funds for the execution, on a grand scale, of works of this character, that it was determined by the home government to avail itself of the offer of a private company as an experimental measure.

3. It is now for consideration whether, under a different state of financial affairs, the system then introduced should be continued, or whether works of irrigation should, as a general rule, in future be carried out under the direct control of the government.

4. The experience that has already been had of the working of irrigation companies tends to show the correctness of the objections to the employment of this agency which those opposed to the system entertained, and which have been now so forcibly put forward, as well by the late governor-general, Lord Elgin, and by Sir William Denison, when temporarily acting as governor-general, as by Mr. Maine, in his minute of the 30th September last; and it appears that however desirable it may be for the government to avail itself of the agency of companies in carrying on railways and other similar works of public utility, the close connection between the interests of the government which receives and those of the rigot (farmer) who pays the rent of the land, and the intimate relations which are thereby created between them, render it very undesirable that works of irrigation, and the arrangements connected with the return from them, by which those interests and relations may be so materially affected, should be in other hands than those of the government.

* * * * * *

7. After carefully considering this important subject in all its bearings, and the able minutes recorded by the several members of your government, I have to signify to you my concurrence in the conclusions at which you have arrived: that the state should undertake directly all the irrigation-works that it can practically manage in preference to intrusting them to private companies; and that when the surplus revenues and available balances prove insufficient to supply the requirements of the country, funds, by means of loans, should be

raised; and I shall be prepared to give favorable attention to the practical steps you may propose to adopt to give to these conclusions.

8. In the mean time it would seem to be premature to inquire what concessions it might in certain contingencies be proper to make to private irrigation-companies.

Undoubtedly, it would be better that such companies should be encouraged than that important irrigation-works should either not be undertaken at all or should be indefinitely postponed.

But since it has been determined that your government shall at once make arrangements for prosecuting such works to the extent of its means, it will be advisable to wait to see whether those means may not suffice of themselves before considering on what terms extraneous aid might be obtained. The objections to irrigation-companies in India may not be insuperable, but they are sufficiently strong to make it desirable that resort should not be had to such companies.

IRRIGATION IN ITALY.

Rain-fall and temperature--Mean and maximum temperature--Comparison with California--Historical sketch--Canals in Lombardy--Tabulations--Canals in Piedmont--Tabulations--Area irrigated in Piedmont; in Lombardy; cost--The Cavour Canal; agreement; history; details of canal --Ownership of canals--Administration--Associations--Marcite meadows--Measurement of water.

If California possessed a rain-fall equal in amount, and distributed in the same way as it is in Italy, she would not require artificial means of water-supply, at least for the staples she now produces.

The mean annual rain-fall of Lombardy and Piedmont differ little, and may be taken at 37 to 38 inches.

In Piedmont 28 1/2 inches fall in the irrigating-months, from March to September inclusive, giving an average of seventy-one rainy days.

The meteorological facts are contained in the following table, viz:

Table showing temperature, rain-fall, and weather during the season of irrigation in Piedmont.

	Mean temperature, Fahrenheit, degrees.	Rain-fall, in inches.	Clear days.	Cloudy days.	Rainy days.
March	45	2.84	13	10	8
April	52	4.14	9	10	11
May	61.5	6.33	8	9	14
June	74.8	3.71	9	11	10
July	74.6	3.37	12	10	9
August	71.5	4.80	11	10	10
September	63	3.37	12	9	9

For Lombardy we have the following table, viz:

Statement of the rain-fall and weather in the irrigated region of Lombardy during the season of irrigation.

	Rain-fall, in inches.	Clear days.	Cloudy days.	Rainy days.
March	2.3	17.5	10.1	3.4
April	3.1	15.9	7.8	6.3
May	3.8	14.1	15.1	1.8
June	3.1	19.4	8.8	0.9
July	2.8	21.7	7.5	0.9
August	3.2	21.3	8.2	1.5
September	3.4	17.8	9.3	2.9
	---	---	---	---
Winter	8	42.2	31.5	13.3
Spring	9.3	47.5	34.7	9.8
Summer	9.2	62.4	26.3	3.3
Autumn	11.8	46.8	32.5	11.7
	38.3	198.9	128	38.1

Including the statistics for other parts of Lombardy, we have about 22 inches of rain-fall in the irrigating-season and about eighteen rainy days.

Table of temperature in Milan from March to September.

	Mean	Maximum	Minimum
March	44.6	62.4	33.2
April	54.8	67.6	40.3
May	64	78.1	49.6
June	70.5	84	56.5
July	71.4	86.5	59.5
August	71.4	86.5	59.5
September	66.4	80	53.4
	---	---	---
Winter	36.1	53.8	18.3
Spring	55	78.1	33.1
Summer	72.8	88.5	56.1
Autumn	56.3	82.6	32.5

The mean temperature in the irrigated region of Lombardy from May to August ranges from 70° to 75°, and the maximum from 85° to 90°.

If Italy, with a meteorology like this, requires irrigation, what shall we say of the necessities of California?

We are without data from complete tables of our own meteorology, but something like the following will not be an inexact statement for a large section of our principal valley: Mean annual rain-fall, 10 inches or less; minimum annual rain-fall, 5 inches; number of clear days in the year, 275; maximum summer-temperature in shade, 110° to 115°, with periods of several weeks in which the thermometer every day passes 100° and sometimes 200 days in succession in which no rain falls.

It is not so much the amount of rain-fall as its distribution which affects the prosperity of agriculture.

In Orissa, (India,) with a rain-fall of 60 inches, there was a terrible famine. In California, with 15 inches well distributed, we often have fine crops.

There are traditions of irrigation in Italy in earlier ages, but the first authentic instance of a canal for this purpose is one taken from the Vettabbia River by the Cistercian monks of Chiaravalle in the twelfth century.

In the twelfth and thirteenth centuries the Naviglio Grande, from the Ticino, was built; and in 1220 the large canal Muzza was commenced. In the fourteenth century no work of importance was executed. In the fifteenth century the canal Martesana, one of the earliest provided with locks, was built. In the interval, from the end of the sixteenth century to the nineteenth century, very few canals were constructed. The canal of Pavia belongs to the nineteenth century. It was first opened in the fourteenth century, but, falling into disuse, it was ordered to be rebuilt by Napoleon I in 1805, and was completed in 1819.

The above enumeration relates to Lombardy.

In Piedmont the canal-system dates from a later age, the first works having been executed in the fourteenth century. In the fifteenth century there was considerable activity in this kind of enterprise, while in the sixteenth, seventeenth, and eighteenth centuries there was but little extension of irrigation. In the nineteenth century we have the canal of Charles Albert and the Cavour Canal from the Po, the last the greatest and perhaps the most unfortunate of all.

The following tables, taken from Col. Baird Smith's work on Italian irrigation, places before us in condensed form the principal facts which we are now concerned to know.

CANALS IN LOMBARDY.

Data in regard to the canals from the Ticino River.

	Navoglio Grande	Berequrdo	Pavia
Date of construction.	1178	1460 1847	1359
Length, in miles.	30.5	11.5	20
Discharge per second, in cubic feet.	1,851	156	213
Area in acres irrigated.	93,440	10,400	9,550
Price of water per foot per second.	$35 to $65	$35 to $65	$35 to $65
Annual expenditure.	$8,500	---	$6,960
Income.	$8,980	---	$9,375
Area irrigated per cubic foot.	61.8	66.6	69.2
Annual indirect returns.	$300,000	$ 31,200	$ 28,650

From other small streams, viz, the Lambro, Olena, &c., canals containing 240 cubic feet irrigate 20,181 acres, giving 84 acres per foot, and furnishing indirect returns of $60,540.

Data in regard to the canals from the Adda River.

	Canal Muzza	Canal Martesanae Naviglio Interno of Milan.	Three small canals
Date of construction.	1220	1457, 1440	---
Length, in miles.	43.5	27.5	---
Volume per second, in cubic feet.	2,652	981	414
Area in acres irrigated in summer.	182,500	58,900	38,000

Data in regard to the canals from the Adda River, cont.

Price of water per foot per second.	$ 4.12	$55 to $65	---
Annual expenditure.	$3,970	6,000	---
Annual income.	$7,380	7,000	---
Irrigation in acres per foot per second.	83.9	67.2	---
Indirect returns.	$522,500	176,700	---

Canals from Brembo, five in number, which carry 298 cubic feet per second, and irrigate 27,425 acres.

Canals from Serito, fourteen in number, carry 501 cubic feet, and irrigate 44,200 acres.

Canals from the right bank of the Oglio, carry 1,372 cubic feet, and irrigate 142,500 acres.

Canals from the left bank of the Oglio, ten in number, carry 1,522 cubic feet, and irrigate 136,432 acres.

Canals from the Mella, six in number, carry 429 cubic feet, and irrigate 36,300 acres.

Canals from the Clisio, four in number, carry 828 cubic feet, and irrigate 74,500 acres.

A canal carrying an average of 510 cubic feet per second is taken from the Mincio, which irrigates 20,500 acres, principally of rice. In addition, this river supplies five small canals, which irrigate a few thousand acres.

CANALS IN THE PIEDMONT.

Canals from the Dora Stura and Orco Rivers.

Seven canals are taken from these streams. They were built at various periods between 1556 and 1790. Their aggregate length is fifty miles. They carry 770 cubic feet of water per second, and irrigate 19,855 acres. The price per acre irrigated is from 62 to 75 cents. The net income is $6,855.

Statistics of canals from the Dora Baltea.

	Canal of Ivrea	Cigliano Canal	Canal del Rolto
Date of construction.	1468	1725	1450
Length in miles.			
main line	44	20	8
branches	55	10	40.5

Statistics of canals from the Dora Baltea, cont.

Discharge in cubic feet per second.	700	650	600
Price per foot.	$80 to $105	$80 to $105	$80 to $105
Net income.	$22,100	$ 26,025	$21,875
Indirect returns.	$90,000	$100,000	$75,000

Statistics of canals from the Sesia, &c.

	Gattinara	Gattinara	Mora	Busca	Rizzo Biraga
Date of construction.	1320	1482	1481	1380	1488
Length of channel, in miles.	23 3/4	2 1/2	32 1/2	39 1/4	88 1/4
Discharge per second, in cubic feet.	100	22.5	130	65	90
Area irrigated, in acres.	4,500	1,250	7,000	6,915	9,059
Price per cubic foot per second.	$40-$50	40-50	157.5	140	140
Net income.	$ 6,000	1,250	5,000	----	----
Indirect returns.	$13,500	3,750	21,000	20,145	27,175

Statistics of canals from the Sesia, &c., cont.

	Sartirana	Sundry canals from Agogna	Sundry canals from Arbogna	Sundry canals from Terdoppio
Date of construction.	1380	various	various	various
Length of channel, in miles.	60 1/2	78	13 1/4	35
Discharge per second, in cubic feet.	220	222	18	136
Area irrigated, in acres.	13,860	20,112	906	7,488
Price per cubic foot per second.	$ 210	175	175	175
Net income.	$17,500	----	----	----
Indirect returns.	$41,580	60,335	2,720	23,465

Statistics of canals from the Ticino, &c.

	Langosco	Sforzesca	Molinara	Castellana	Magna	Canals from springs
Discharge/second, in cubic feet.	249	216	25.4	114	25	788
Area irrigated, in acres.	19,142	14,878	2,483	9,125	2,040	52,500
Price of water/ foot/second.	$210	159	113	98	98	---
Net income.	---	$7,500	---	---	---	---
Indirect returns.	$56,925	44,635	7,450	27,375	6,120	157,500

The Cavour Canal taken from the Po at Chivasso is intended to carry 3,885 feet per second.

This completes the enumeration of the principal works in Lombardy and Piedmont.

To gather the main facts in a summary form, it may be stated, first, for Piedmont, that the total quantity of water applied to irrigation is 8,290 cubic feet per second, not counting the supply of the Cavour Canal.

The total area of irrigable land commanded by these canals is stated to be 1,335,680 acres. If we deduct one-third for roads, villages, marshes, &c., the net irrigable land will be about 900,000 acres, of which 306,600 are actually irrigated.

If we add the scattered irrigation in the upper valleys of Piedmont not before included, amounting to 180,000 acres, the total area irrigated is 486,600 acres.

In particular districts the area actually irrigated is about half of the irrigable area.

In Lombardy the area actually irrigated at the date of Col. Baird Smith's report, 1851, was 1,074,129 acres, which is about one-fifth of the productive area.

Between the rivers Ticino and Adda nearly nine-tenths of the surface, between the Adda and the Oglio two-tenths, and between the Oglio and the Adige one-seventh of the plain are irrigated. It is estimated that the aggregate length of the canals and their principal branches in Lombardy exceeds 4,500 miles.

To sum up, we may state that Italy employs for irrigation more than 24,000 cubic feet of water per second, supplying 1,600,000 acres of land.

It is estimated that there have been expended for the irrigation of 1,000,000 acres in Lombardy not less than $200,000,000. This expenditure has been spread over seven hundred years, and has made Lombardy a garden. This estimate, however, is made from very incomplete and uncertain data, and is supposed to cover outlay made for every purpose connected with irrigation, not only the construction of the channels, large and small,

the aqueducts and siphons, but also the adaptation of the ground for the special irrigation required. This expenditure, therefore, includes not only that made by the owners of the canals, but also that incurred by the cultivators. The returns from this large investment of capital are to be sought in the indirect revenues accruing to the government from the increased production and the general prosperity of the country.

The canals are chiefly owned by the government; some, however, are in private hands. The same lesson is to be learned here as in India; *as a financial investment for private parties, irrigation-works have not generally been favorable.*

So far as the government is concerned, it is to be said that on the old canals the many private grants of water, made ages ago for services rendered to the state or from caprice, detract largely from the revenue, and they should be considered in estimating the financial character of this kind of enterprise.

The Cavour Canal, before mentioned, is the most important work of the kind in Italy; and, inasmuch as it is a recent construction, and as it was made by a joint-stock company, it will be of interest to inquire what conditions were considered necessary by the government in the light of its extended experience of the working and requirements of irrigation. It was the intention of the government to construct this canal; but on account of its financial difficulties, arising from the wars with Austria and Russia, it was prevented from carrying out the project, and was induced to intrust it to a corporation.

The principal points of the contract between the government and the English company, made in 1862, are as follows, viz:

The company were to construct and work a canal from the river Po, to contain 3,885 cubic feet per second, to irrigate the Novarese and Lorvellino districts, and to combine with this the waters of the Dora Baltea, to be used also in the Vercellese. The company was to commence the work in six months, and to complete it within four years, in spite of all circumstances of every kind.

The government granted a reduction of 50 per cent. of the customs-duties on all material introduced for the construction and maintenance, a complete remission of duties on all instruments and tools, and a partial remission of registration-duties on all deeds and contracts.

The government sold to the company the royal canals from the Dora Baltea, with every appurtenance of factories, mills, &c., for the sum of $4,060,000, to be paid in installments.

The company is to have the use of the irrigation for fifty consecutive irrigating-years, after which time it shall revert to the state, without any compensation whatever to be made to the company.

The company is to raise a capital of $16,000,000, of which $10,680,000 is to be devoted to the construction of the new works, and the remainder to be applied to the purchase of the crown canals above mentioned, and other canals or volumes of water.

The government guarantees interest to the amount of 6 per cent. annually on the capital of $16,000,000.

The company is authorized to issue 6 per cent. bonds to the extent of $11,000,000, the shares to be issued for $5,000,000. The sum raised by

bonds is to be deposited in the public treasury, to be issued to the company as required. The government must approve of the works to be constructed; and it has the right to superintend their execution, and to inspect the management of the canal.

The amount of the water-rate and the price of water-power "shall be fixed by the government in consultation with the society, and approximation to the average of current prices being agreed on, and the society shall not vary the prices without the approval of the government."

The company is obliged to lease the water carried beyond the Sesia to an association of proprietors at a price to be fixed in the way just stated.

The obligation of the government to pay the 6 per cent. interest is conditional, and shall only apply when the net income of the canals shall be insufficient to meet the expense.

The canal-rates shall be collected by the proper officer of the government in the same way that public taxes are collected.

The company shall deposit in the treasury, as security, $200,000 in Italian bonds at their nominal value, to be refunded when the company shall have expended $2,000,000.

The state shall have the right to purchase the works after twenty years' occupation, paying the capital corresponding to the mean annual net income for the preceding three years at 5 per cent., deducting the sum previously paid by the government on account of its guarantee.

These are the important points of the agreement, and it must be confessed that the government made a good bargain.

The history of the enterprise is melancholy. In the first place, the Po, instead of carrying 4,000 feet a second in its lowest stage, falls to 1,500 feet. It is simply impossible to understand how such an error could have been committed in Italy.

The Dora Baltea has, however, water in sufficient excess of its requirements, and it is possible to remedy the error by a comparatively small expenditure.

Then there was extravagance and bad management on the part of the company, and the government declined to pay interest on the capital because the works were not absolutely completed within the specified time.

By decision of the courts, however, the government was required to pay the interest. Under all these disadvantages, the company failed, and the enterprise passed into the hands of its creditors.

The character of the works on this canal may perhaps be in some degree realized by an enumeration of its principal features.

The canal is 55 miles long, and at its head it is 131 feet wide on the bottom, and 6 feet in depth. The general slope of the bed is 1 in 4,000; in places it is as much as 1 in 2,800. The side-slopes are one upon one; but on the curves and on the embanked portions, the slopes are revetted with masonry. These dimensions give a velocity varying from 4 1/2 to 5 feet a second. The soil, however, is gravelly.

The canal crosses five streams of torrential character by aqueducts and siphons of considerable length; the aqueducts being approached by long embankments.

There are 345 bridges, or passages, for water over and under the canal, being more than six for each mile. These constructions are of the most substantial character.

The cost of the work, however, is largely due to the fact that the canal is carried across the drainage of the country. Its alignment would have its counterpart in California in a canal skirting the base of the foot-hills of the Sierra Nevada, and crossing, by aqueducts or by siphons, the successive parallel streams which discharge into the Sacramento or into the San Joaquin River. Indeed, the resemblance between the topography of the southern flank of the Alps and the eastern side of the valley of California is complete. The Sierra corresponds to the Alps, the Po to the San Joaquin, and the feature of parallel drainage-lines is common to both.

The canals are quite generally owned by the state. They are under the control of the finance department of the government, which has a staff of engineers to superintend the repairs and to see that the works are kept in efficient order.

The usual practice is for the government to farm out the canals to contractors for a period of nine years. The contractors arrange with the cultivators for the distribution and measurement of the water, and fix the rate of payment under some restrictions.

Disputes between the contractors and cultivators are decided by the civil tribunals.

Each canal forms a district for administration; it may, however, include more than one district.

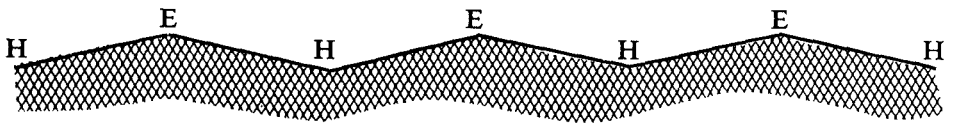
In each district, under regulations prescribed by the government, the irrigators form associations, which administer the affairs connected with the distribution and use of the water.

We need make no further reference here to the description of these associations, for the reason that we attach to this report, as an appendix, a full account of one established by Count Cavour about twenty years ago, for the irrigation of the Vercellese district. This association may be regarded as the most recent result of Italian experience. It embodies the principles which are believed in Italy to be most conducive to the interests of all concerned in irrigation.

This description is taken from a book by Lieut. G. C. S. Moncrieff, Royal Engineers, entitled "Irrigation in Southern Europe."

We should infer, from the meteorological details already given, that cereals and most other products scarcely need irrigation in Italy. Indian corn and flax are irrigated to some extent, but irrigation is mainly confined to rice-cultivation in the summer, and to meadows in the winter. These meadows are devoted to the cultivation of a grass called marcite. This crop requires that a thin film of water shall pass continuously or almost without intermission, except at the periods of cutting, over the grass. This is secured by shaping the land in planes about 30 feet wide, with a slope of 1 in 12 or 15. On the crest of the planes there is an irrigating-channel, from which the water is spread over the land; the surplus being carried off by drainage-channels.

The accompanying section of the land will convey an idea of the arrangement for the distribution of the water.



E, minor irrigating channels, generally 12 inches wide and 6 or 7 deep.
H, minor drainage channels, about half the above dimensions.

The amount of water necessary for these meadows exceeds, beyond comparison, that required for any other cultivation. A cubic foot per second, if economized, may irrigate as much as three acres. The production is very great. The meadows near Milan are cut seven times a year. An ordinary result is 50 tons a year, with exceptional yields of 75 tons, per acre. These meadows are, however, fertilized by the sewerage of Milan, which is distributed over the land directly by the irrigating-channels. In less-favored localities, the yield falls as low as 24 tons per acre. This production cannot, however, be sustained unless the land is richly manured.

On the crown-canals, water is measured as it leaves the principal channels by an apparatus known as the module. There are various examples in different provinces but the best known and most reliable is that used in the Milanese.

It seems scarcely necessary here to give a description of the arrangements made for this purpose, inasmuch as the information is readily accessible. We may, however, mention that the principle of the measurement is that the head of water is kept constant, whatever may be the changes in the level of the canal. After the water leaves the main channels, there does not seem to be a uniform practice of measuring it on its distribution into the secondary ditches. There are so many usages in this country, sanctioned by long periods of time, that it has hitherto been impracticable to introduce complete and thorough measurement.

There are always some persons who profit by the absence of regulations on this point, and their influence exerted against change has proved sufficient to defeat the purpose of the government.

IRRIGATION IN SPAIN.

Rain-fall and temperature--Comparison with California--Value of irrigated land in various parts of Spain--Irrigation introduced by the Moors--Water annexed to land in Valencia--Variety in ownership of water--Value of water in different provinces--Spanish law--Method of obtaining a grant of water--Privileges to irrigation-enterprises--Exemption from taxation--Minority compelled to pay their part for canals--Subsidies; how given--Position of government of Spain--Irrigating-associations--Subsidies to canals--Area of irrigation--

Huerta of Valencia--Administration of irrigation--General assembly--Syndic --Kinds of cultivation--Drought--Tribunal for deciding disputes--Its composition and modes of procedure--The canal of Mencade.

In some parts of Spain we seem to be near home. There is something familiar in a rain-fall of 7 inches and a temperature of 111°.

The mean annual rain-fall for different parts of Spain for four years, from 1858 to 1861.

	Inches.	
Granada	33.4	
Seville	22.5	
Valadolid	20.9	In 1859, at Alicante
Saragossa	17.0	there were only 7.1
Valencia	15.9	inches of rain.
Alicante	13.6	
Madrid	12.0	

Table of rain-fall and temperature for the irrigating-months, from March to September.

	Mean rain-fall, in inches.	Mean temperature, in degrees, Fahrenheit.	Maximum temperature, in degrees, Fahrenheit.
Madrid	5.31	64.69	98
Alicante	7.66	69.41	94
Valadolid	8.98	62.51	90
Seville	5.45	77.98	111

A comparison of the meteorology of these parts of Spain and of the irrigated portions of Italy, will show for Spain both a higher temperature and a smaller rain-fall.

The climate in our interior valleys differs from that of Spain, in the fact that the latter country has a summer rain-fall ranging from 5 to 9 inches, whereas in California we often have no rain worth measuring from April to December; and generally from the beginning of May to the end of October not a rain-cloud obscures the sun.

Spain, by common consent, needs irrigation, and perhaps of all the countries in the world it best repays irrigating.

We might establish the remunerative character of this mode of cultivation in other ways, but it is probable that no way can be more satisfactory than to give the values of land as established by sales, both of irrigated and of unirrigated land.

Near the city of Valencia,[38] irrigated land is sold at prices running from $700 to $900 per acre, and at a distance from the city from $400 to $500 per acre, while land of the same quality not irrigated is sold at $80 or less per acre.

Don Juan Ribera, a Spanish engineer, states that land near Madrid[39] is increased in value by irrigation from four to ten fold, land of the lowest price being most appreciated in value.

From sales made at Castellon[40] in 1859, it appears that the average price of irrigated land was $700 per acre, while unirrigated land in the same neighborhood was sold for $50 per acre.

Parts of the *huerta* of Murcia have been sold at $2,500 per acre, dry land close by being worth $150.

At San Fernando, near Madrid, the rental of irrigated land is $25 per acre, which is the price in fee of dry land in the vicinity.

In the valley of the Esla River irrigated land is worth $600 per acre, and dry land $50.

In the valley of the Tagus it is said the produce from irrigated land is twelve times that from unirrigated land. In parts of France where irrigation is not nearly so much needed, irrigated land is only appreciated 50 per cent. by irrigating.

Spain may be described as a country where the water is more valuable than the land in a ratio of from 5 to 20, and we feel assured that the same proposition is equally true of large parts of California.

Spain is, from the value attached to water, an interesting study. It is interesting to know what steps have in recent years been taken to extend the use of water, and what systems have been adopted.

The Spaniards have an experience of a thousand years behind them, and they ought to be convinced of the value of this mode of cultivation.

There is probably no part of the world where water is more carefully applied, and there certainly is no country where the legislation is more clear and precise.

Irrigation in Spain is a legacy left by the Moors. All or nearly all of the old systems were the work of this wonderful people. Not only the works but the customs of the Moors remain in some provinces almost untouched since their departure. These customs may be said to be imbedded in the hearts and minds of the people of certain provinces, and we must regard it as a tribute to the intelligence of the conquered race that their regulations, adopted by their enemies, have been able to exercise a sway so complete that the efforts of rulers and the progress of events have alike failed to change them in their essential features.

We find in Spain every variety in administrative systems for using water. In Valencia, in the lands irrigated from the Jucar River, and in Murviedro, the water and the land are, so to speak, married, without a possibility of divorce. When the land is sold, the water that irrigates it goes with it; neither can be sold separately. The irrigator cannot even

dispose of his turn or privilege of water. The same is true in the province of Murcia, and at Almansa.

As Elche, on the other hand, the water belongs to parties who do not own the land. The land has no rights. When the farmer needs water, he buys it as he buys any other article. There is a daily water exchange, where one may buy the use of water in an irrigating channel for twenty-four hours, beginning at six in the evening. The prices that are stated to have been paid in times of scarcity, tax our credulity very much.

In 1861 it is said that water was sold at more than $11,000 per cubic foot a second.

At Lorca there is an auction of water held daily.

These are all old works, where the customs of past ages prevail. The new canals are generally built and owned by capitalists, under conditions which will hereafter be explained. On the Heuares Canal, just built, it appears that the company owning the works made agreements with the farmers before building as to the price to be paid for irrigation. The government fixed the value of water on this canal to be $1,875 for one cubic foot a second for one year.

It will be remembered that in Italy the annual value of the same quantity is about $75 to $80.

The different meteorologies of the two countries make the basis of this difference of value.

On the Heuares Canal to cover an acre with twelve inches of water costs $2.88; on the Esla Canal, $1.70.

At Alicante the price of 16,000 cubic feet of water, which is about 4 1/4 inches over an acre, has varied, according to scarcity, from 50 cents to $13.

At Larca the average price of 17,500 cubic feet of water, nearly 5 inches over an acre, is $6.25.

The canal Llobregat charges on an average $2.75 per acre, and as high as $4.25.

The canal of Urgel charges $4.75 per acre. In Malaga the price is about the same.

On the old Moorish works, which are now the property of the irrigators, the price is only what is necessary to pay the expenses of the works and keep them in repair.

The farmers have agreed to take water from a new canal in Navarra, and to pay $3 per acre for four irrigations in a season. An irrigation in Spain is generally from 2 1/2 to 3 inches in depth.

SPANISH LAW IN REGARD TO CANALS, AND CONDITIONS OF AGREEMENTS MADE WITH PRIVATE COMPANIES.

The latest enactment, which seems to be most complete and detailed, and which contains three hundred paragraphs, is dated August 3, 1866. Although all the provisions would doubtless be of interest to those called upon to legislate upon the subject of water, we cannot do more than refer to those points which bear immediately upon our subject.

Article 236 states that all grants of water made to owners of land for its irrigation shall be in perpetuity. All grants made to parties to irrigate the lands of others shall be for a period not exceeding ninety-nine years, which period expired, the works shall become the property of the irrigators. An application for a grant of water shall be accompanied by proof that the applicant owns the land he proposes to irrigate; or if not, the rates of payment proposed to be paid by the parties who own the land or who are to buy the water; or if a particular district is to be irrigated by the owners thereof, that the agreement made by the majority of the owners reckoned by the area owned. The project is then to be advertised, and objections may be made for a month. The project is referred to various authorities, to ascertain whether it is desirable, whether it interferes with any vested rights, whether it promises to endanger the public health, or whether the constructions proposed are suitable. Any grant of water is subject to rights of other parties previously established.

Certain privileges are granted to undertakings of this class, as follow, viz:

1st. To quarry on the public land. Sites for the necessary works, shops, kilns, &c., on the public lands are given free.

2d. Exemption from certain charges required in transfer of property.

3d. The capital invested is exempted from tax of every kind; and all foreign capital invested in these enterprises will be under the protection of the government, and it shall never be confiscated in time of war.

4th. Employes have certain local privileges. If the company allows the works to fall into bad repair, and does not restore them within the period assigned by the government, or if the new works shall not be finished in the stipulated time, they may be sold at public auction to the highest bidder.

All the land included in any project which is called for by the majority of the proprietors shall pay the approved rate, whether the owners wish to take water or not; and those who refuse to pay are obliged to sell their lands to the company at a price equal to the assessed value of the land, for taxation, increased by 50 per cent. If the company declines to purchase the lands at this price, the proprietor shall be exempt from any payment.

The law of April 22, 1849, provides, that for ten years after the works are completed all products of irrigation shall be free from taxation.

All land brought under irrigation is taxed as unirrigated land for ten years.

The law of July 11, 1865, appropriated $5,000,000 to be given as subsidy or as loans, without interest, to irrigating enterprises, in sums not to exceed $100,000 for each enterprise. The special authority of the Cortes is necessary to permit a larger grant. This subsidy is generally given to the amount of 15 per cent. of the estimated cost, as certified by the government engineers, and it is paid in three installments:

1st. When the earth-work is finished.
2d. When the bridges and culverts are finished.
3d. When the work is completed and the irrigating is begun.

The attitude of the government toward the administration of these enterprises is commended by M. Aymard in the following terms:

> We may inquire, What is the nature of the action of the government in regard to enterprises of irrigation? What is the character of its intervention or supervision? Does it lead or does it follow the people?
>
> The government is in advance of the people, but it does not exercise an injudicious pressure. Where customs sanctioned by antiquity prevail, it does not seek to overthrow them merely for the purpose of securing unity of administration.
>
> It is in advance of the people in this sense, namely, that it lays down with clearness and precision in the laws the modern principles of the administration, so that the moment that the necessity for a reform is felt, the people are at once informed in what direction that reform is to be sought.

In regard to the terms on which new concessions are granted, the same author says:

> In the activity which has recently prevailed in the extension of enterprises of irrigation, the problem was to guard the rights and interests of future generations, while making such concessions to the commercial spirit of the present as would induce the extension of these necessary works. In its decrees the government lays down with great wisdom the general terms of all concessions of water-franchises, and defines the respective rights of the proprietors, and of the users; so that enterprises of this character may be undertaken without hesitation or embarrassment. The outline of every possible enterprise is defined in the statutes, and in each particular case it is only necessary to fill in the details.

One clause in these statutes provides that in every irrigating-district or community there ought to be established a syndicate or association, and a system of regulations fixing the details in every respect concerning the use of the water; which regulations must be approved by the government or by the provincial authorities, as the case may be.

The general principle which forms the base of the syndicate is this, namely, that the administration of the water-supply and use shall be in the hands and under the control of the irrigators.

We see that the Spanish systems of a thousand years' duration lead to the same general conclusion that the experience in Italy has established and exemplified in the association for the irrigation of the Vercellese, an account of which is given elsewhere.

This conclusion may be stated in these terms: that where the irrigators do not own the irrigating-works, they ought nevertheless to have the control of the distribution of the water, and of the details of irrigation.

A conclusion which is fortified by the experience of hundreds of years in Italy and Spain, where the people cannot be supposed to be more familiar with the principles of self-government than are our own people, which is supported by the wisdom of a man like Cavour, which promises relief from the difficulties attending the administration of water by capitalists having no direct interest in the land, but looking for the best return for their money invested, and which, moreover, is congenial to the habits and feelings of people like our own, must, perhaps, with modifications, prove the solution of our own vexed problem.

It is worthy of remark, and it is confirmatory of the general conclusions derived from the experience elsewhere, that in a country where irrigation is so desirable, and where its effect is to increase in so striking a manner the value of the lands, the government feels obliged to aid works of this kind by subsidy and by exemption from taxes.

According to the official reports, the area of irrigated land in Spain if four thousand four hundred and thirty-nine square miles.

The principal canals, however, irrigate only 500,000 acres. There are many small canals and a few tanks or reservoirs, which increase this area considerably. If we accept the official reports, the greater part of the land must be irrigated by wheels or *norias*. These wheels have buckets or jars attached to the circumferences, by means of which the water is raised. The motive power may be the current of the river, or it may be animal power.

We close this review of Spanish irrigation by a brief description of the agriculture and system of administration in the highly-cultivated *huerta* of Valencia.

This district extends for eight or nine miles along the river Guadalaviar, from which the canals which irrigate it are derived.

It has been under this kind of cultivation for perhaps a thousand years. The Moors introduced irrigation, and the executive and judicial system established by them retains to this day its essential characteristics.

The water in this district is, as has already been stated, annexed to the land, and when land is sold the right to water goes with it. A person cannot even give to another the water to which he has a right; if he does not use it, it reverts to the common benefit.

The plain of Valencia is irrigated by eight small canals, four of which are on each side of the river. Each canal is entitled to an aliquot part of the river-supply, and the proportions are established by the levels of the sills of the head-works, which are of masonry, and which have remained unchanged since the days of the Moors. It is, however, only in the low stages of the river that it becomes essential to observe the prescribed division of water, for at other periods there is an abundance for all.

The aggregate length of these canals is but forty-two miles. The longest is but twelve miles in length. The dams are of masonry.

The administration of these canals is at least curious, and it will be interesting to recount it briefly.

Each canal forms a district, the irrigators of which meet once in two years to elect a permanent committee of administration, to assess the expenses or taxes, and to elect the officers of the district. The principal officer is called the syndic; we should probably call him the superintendent. He must be an actual cultivator; not a proprietor merely, but one who actually holds the plow. He must have a good character and be owner of a certain quantity of land in his own zone or district. He is elected by a majority of votes, and he may be re-elected. His term of office varies between two and four years. He is chief administrator; he expends the funds, and in time of drought he is an absolute dictator in regard to the distribution of the water. The other employes are appointed by the syndic, or by the permanent committee, or sometimes they are elected by the general assembly.

Usually the taxes are assessed by the general assembly. Generally each irrigator pays according to the land under cultivation, but not always so. In some cases he pays in a measure proportionately to the quantity of water used. The taxes are collected in a summary manner. If any one fail[s] to pay his taxes, he is deprived of the use of the water, and if he take[s] it he is liable to a severe fine; or if any official shall allow him to take water, the latter is exposed to the same fine.

There is no regulating machinery for the distribution of water. The arrangements are at the discretion of the officials, who keep themselves informed as to the condition of the crops, and who supply water to those which seem to need it most. No cultivator can claim a definite quantity of water.

The cultivation is various; hemp, corn, wheat, beans, pears, melons, artichokes, and peppers are among the products of the soil. Hemp is regarded as the most valuable crop. It is cut in July, before the water gets very low, and therefore it seldom suffers from scarcity of water.

In times of drought the syndic gives water to the crop that needs it most; keeping in view, however, the value of the crop. Hemp being the most valuable crop, receives attention first if it needs it, which is seldom the case; next come artichokes, the order being established by long custom. If all of a given crop cannot be saved, the water is applied to half of each field, the other half being allowed to suffer. The decision is in the hands of the officials, none of the cultivators being permitted to take water without permission.

This is certainly a very rigorous kind of administration. It is democratic so far as its deliberations and constitution are concerned, but in its action it is essentially autocratic. Doubtless the long line of customs descending from a thousand years serves in practice as a guide for the action of the syndic, and divests it, in a measure, of its arbitrary appearance. The responsibility is, however, not divided. In times of drought some responsibility must be taken, and one man can take it better than a number. The working of the system must be favorable, or it would long since have fallen under the opposition of its enemies.

These canals have a curious tribunal, which has come down from the Moors, and which is as simple and untechnical in its constitution and in its modes of procedure as can be desired. Its proceedings are not recorded, unless at the request of one or both of the parties concerned. It enforces its decrees in a summary manner, and there is no appeal from its decisions.

This tribunal of the canals is composed of the syndics of the canals of the plains. It meets every Thursday at 11 o'clock in the public square in front of the Cathedral in Valencia. The judges are seated, while the parties concerned and the spectators stand respectfully a few paces distant. The syndic in whose district the grievance or offense was committed brings the case before the court. He questions the witnesses and presents the case, but he does not vote. When the case is heard, the judges discuss in a low tone for a few minutes, and announce their decision. No expense is incurred by the parties to the case, if the fines or damages assessed are paid at once. If they are not so paid, the tribunal has power to enforce its decisions by processes which entail expense upon the recusant party. The fines attached to particular offenses are stated in a code of laws. The jurisdiction of the court is absolute in matters of fact and police over those who appear before it. Any person may decline to appear before the tribunal. If, having been twice summoned, any person shall fail to appear, the matter is turned over to the ordinary courts, where its adjudication is attended with considerable expense. It is said that cultivators rarely fail to appear before this tribunal when summoned.

It may well be supposed that this institution has often been assailed. A court of peasant judges, whose proceedings are not recorded and whose decisions admit of no appeal, could not fail to attract criticism and invite intervention. The government has more than once attempted to make changes in harmony with the usual course of procedure, but the steadfast attachment of the people interested in the tribunal has sufficed to maintain it substantially as it descended from the Moors. Whatever may be its defects, we cannot doubt that it has dispensed even-handed justice; otherwise it could not have existed so long.

The canal of Moncade, which is also taken from the Guadalaviar River, has some differences in administration which indicate the character of the changes which the government has wished to make in the case just described. This association has a code of regulations which prescribes fines for the various offenses. The superintendent or syndic of the canal is invested with authority to impose fines in accordance with the code. The parties concerned have the right of appeal to a court elected by the irrigators, which resembles in many respects the tribunal of the canals, and there is a further right of appeal to one of the ordinary civil courts. On this canal each irrigator has a right to water on fixed days for a certain number of hours.

IRRIGATION IN FRANCE.

Government owns canals--How canals are built and how managed.

Irrigation is quite extensively practiced in France, and several new canals have been built in the past few years.

There is nothing so specially distinctive in French irrigation as to require detailed description. The principle of management of works by the irrigators applies here as well as in Spain and Italy. There is, however, more interference by the government.

The government owns no canals. They are generally built by the land-owners. The government encourages the construction of canals.

In the charter of the *Carpentras* Canal, built in 1854, the irrigators were guaranteed that no increase of the land-assessment should be made for twenty-five years after completion of the works.

There is no provision in the French law corresponding to the Spanish statute which permits a majority of proprietors to carry on an irrigation enterprise and compels the minority to bear their share of the expense.

When a charter for a canal is given it states the quantity of water which is granted. The plans for the works must be approved by the government. In some cases the canals are built under direction of engineers of the Corps of Ponts et Chausees. In all cases the works are periodically inspected by engineers of this corps.

CHAPTER V.

1. Cost of irrigation--Quantity of water required--Secondary and tertiary ditches to be made by cultivators--Canals and primary ditches will cost about $10 per acre irrigated.
2. Conclusions--Large bodies of land in "the great Valley of California" require irrigation; abundance of water; irrigation much needed--Cost--Ignorance of the subject--A comprehensive system cannot be devised by the farmers--Duty of government--Proper laws depend on reconnaissance and surveys--Irrigation will be the work of time--Land and water should be joined together--State and counties benefitted--Private capital--Relation of the United States to irrigation--Supervision.

COST OF IRRIGATION.

Before making an estimate of the cost of canals, it is necessary to inquire how much water is required to irrigate an acre of land. It will readily be understood that the quantity will depend upon a number of considerations. In the first place, it will depend upon the character of the soil, whether sandy or clayey; upon the character of the substratum, whether pervious or impervious, and upon the depth and inclination of an impervious stratum. It will depend upon the character of the cultivation. Rice and sugar fields, vegetable-gardens, orchards, and meadows require more water than cereals.