WITH THE WRITER'S COMPLIMENTS

130 A 91 (5)

LECTURE

AND

ARTICLES ON IRRIGATION

IN

INDIA, AMERICA, EGYPT, AND AUSTRALIA

BY

ROBERT WALLACE, F.L.S., F.C.S., F.R.S.ED., &c.

PROFESSOR OF AGRICULTURE AND RURAL ECONOMY IN THE UNIVERSITY OF EDINBURGH;

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INTRODUCTION

In the humid climate of our sea-girt country, little is seen of the artificial application of water for the encouragement of crop growth, with the few exceptions where an effort is being made to utilise a modicum of town sewage; and we are too liable to overlook the importance of irrigation in those many regions of the earth where with a deficient natural rainfall are associated a cloudless sky and a scorching sun which reduce to the condition of a desert, soils which but for the want of moisture would bear abundant and varied crops and support teeming millions of population. With the present plethora of wheat and of butcher meat shipped to us from so many distant lands, it would at first sight seem to be unnecessary to trouble about the future of the world's food, but abundant and cheap food is closely followed by increase of population, especially under such conditions as now prevail among our labouring classes. Employment is general, the standard of remuneration for labour has been steadily advancing during recent years, and the working classes occupy a more comfortable and more independent position than they have ever before experienced. The rapid increase of population is a natural and certain consequence, and it is a matter of no little general interest to foreshadow the results in the light of mercantile and social changes which are progressing surely, if slowly. Agricultural occupations continue to employ steadily declining numbers of workers, while our foreign rivals in international trade, led by Germany, make ground upon us in a way which recent statistics show to be truly alarming. Should foreign competition become more acute, as is highly probable, the impetus given to the expansion of population by our present industrial prosperity would probably be too clusively dependent upon home occupations. The influence of the English-speaking race in the world's government will be closely bound up with the width of its distribution and the numbers it will be able to muster as combatants in the great bloodless industrial encounters of the future. It is well to examine, before actual necessity approaches, the outlets which are open for our surplus capital and our surplus population—outlets which will act as safety-valves to prevent overcrowding and consequent social disturbances at home and be the means of strengthening abroad the position of a race which, because of its successful enterprise, has roused the jealousy of other sections of the civilised world. Of the different partially-developed means for the support of growing populations, irrigation forms one of the most important and most promising, as it brings into utility regions which would be otherwise barren, and can be employed for the growth of an infinite variety of crops and the support of all descriptions of farm animals.

IRRIGATION IN INDIA.

IRRIGATION in India, always an interesting subject, is of special interest at this time,—after the close of the great famine of 1896-8—which, in spite of the excellence of the famine-relief machinery of the Indian Government and the praise-worthy individual efforts of the British officers, on whom the heavy burden of work fell, will long remain a regretable memory among millions of our Indian fellow-subjects. It has been said, and said truly, within certain limits, and with the necessary explanatory notes, that 'Irrigation is the only possible remedy for drought.' Artificial rain-making, which so agitated certain American enthusiasts for a time, having failed, irrigation is the only practical way by which the moisture, indispensable for plant growth, can be provided when Nature stints her supply. When this is admitted we must not jump to the conclusion that it must necessarily be expedient to vastly extend the area of irrigation in India until no further recurrence of famine be possible. Irrigation with all its two-edged sword, cut in two opposite directions. It can be productive of an incalcuable amount of injury when practised in ignorance or with indiscretion. In view of such widely divergent possible results it is necessary to study carefully the natural conditions which are to be encountered in India, and in the light of the best of all possible guides, viz., experience, to determine what ought to be and what ought not to be attempted. In round figures the total cultivated area of British India is not far short of 200,000,000 acres, and of that probably not more than 30,000,000 acres are, as a rule, irrigated in one season. But it should not be forgotten that the irrigated area embraces the most fertile soils in the country—the deep alluvial areas that have received for generations the washings of rich deposits from the higher ground. So superior is it in crop-bearing capacity that it is estimated to produce annually 20,000,000 tons of food, or sufficient in famine times to support 120,000,000 people, or nearly half the native population of India. It is confidently urged by some enthusiasts that to double the irrigated area would be a solution of the recurring and vexatious famine difficulty, the last illustration of which has, during 1896-8, according to the estimate of the Secretary of State for India, cost the Government £10,000,000 sterling.* That such a proposal is ridiculous and even impossible will subsequently transpire when we consider the salient features of the question. Most of the important recommendations regarding the extension of irrigation made by the Famine Commission of 1880 have already been carried out, and although a few instances in which the possible benefit is undoubted still remain to be attended to—such as that relative to the Ken Canal in Banda District, N.W.P.—the Government irrigation work of the future lies within the debatable zone which divides successful from unsuccessful undertakings of the kind. Irrigation in India is accomplished by calling into requisition three different sources of water supply, viz.—(1) wells, (2) canals, and (3) tanks, lakes, and rivers. The canal system involving much capital outlay, is naturally the one under Government management. The others being capable

* The direct and indirect loss by the famine of 1896-8 to the Government of India was Rx 7,512,000 in 1896-7; Rx 9,717,000 in 1897-8; and Rx 796,000 (estimated) in 1898-9.

of application on a small scale are within the reach and to a great extent under the control of private enterprise. The total amount of public money which has been expended on over 30,000 miles of canals now in operation in India approximates to 32,000,000 Rx (Rx=tens of rupees or "rupee-pounds"). Financial success is not an appropriate standard by which to gauge the importance of work which involves such vast moral responsibilities on a benign Government, but, nevertheless, it is gratifying to know that the canal system of the country does bring in a revenue which covers the interest on invested capital. A more striking view of the situation is presented by one of the greatest living authorities on Indian irrigation, who says: 'It may be broadly calculated that the value of the crops which would have perished if unwatered, or would not have been sown at all if the canals had not existed, equals in each ordinary year at least half the capital expended on them.' There are two essential conditions, besides other minor considerations of more or less importance, which contribute to success in the construction of canals in India: 1st, That there be a sufficient supply of water within command in times of drought, as well as during periods of normal rainfall; and, 2nd, that the character of the soil and the geological formation of the dictrict be such that the introduction of water will not convert it into a swamp, or 'substitute malaria for famine.' The old maxim that the enterprise should also be a paying speculation must be given up now that the most promising works in this respect have been constructed. An irrigation system ought at least to pay the working expenses, but above this point it becomes a matter of expediency for Government to determine whether or not an unremunerative or partly remunerative expenditure on irrigation is the least costly of the several different ways by which the horrors of famine may be combated in India.

The construction of a system of canals sufficient to save a district from famine, which, in a more or less irregular way, occurs about once in ten years, might, under certain conditions, so waterlog the soil during the other nine years as to more than counterbalance the advantage of the immunity conferred. In a hot country like India, where evaporation from the soil is extremely active if the water-table or underground water supply be allowed to rise too high, efflorescences of soluble alkaline salts, brought up by the ascending current of water required to feed the evaporation, rapidly accumulate on the surface. Soils rendered barren from this cause are known by the name of 'Usar' or 'Reh' soils in some of the too well-irrigated, or, more correctly, badly-drained districts of Northern India. When a district which, as a rule, receives a sufficient supply of rain to produce satisfactory crops is canalised, the cultivators do not avail themselves of the advantages offered, at least to the full extent, unless they are driven to do so by drought. The additional labour and probably the personal trouble is not compensated for by the additional yield in a year of abundance, and, as a natural consequence, irrigation systems in such districts have to be transferred for the greater part of the time from the class of paying to that of non-paying ventures. The record of the Upper and Lower Ganges canals is a good typical example of the irregular use of irrigation water by the native cultivator. After gradually expanding to 1,494,000 acres in 1891-2 (a season of deficient rainfall) the area irrigated shrunk to 783,000 acres in 1894-5, when rain was plentiful. The value of the canals in times of drought was nevertheless fully demonstrated.

Of all the political divisions of India, Bombay is least favourably situated for successful irrigation. Perennial snow-fed rivers do not there exist, and, as a rule, the staple crops can be reared without artificial watering. The black cotton soil which stretches from Bombay through the central plateau of the Indian continent is not well adapted for irrigation purposes, and its great water-retaining power makes it more independent than most soils of an irrigation supply. It becomes extremely sticky when wet, and if worked in this state, bakes into a brick-like condition, which renders it worthless for the season. In Bombay not more than 70,000 acres have been irrigated from Government canals in any one year, and the patronage of the cultivator is so uncertain that they do little more than pay working expenses.

The Punjab is the typical province for canal i
Water is to be had in any quantity from the snow-f
the rainfall is so insignificant that it never compet

irrigation supply, and the soil, with the exception of the alluvial banks of the Jumna, is valueless without irrigation. The water-table is so deeply situated in an open sandy stratum that waterlogging or malaria cannot possibly occur. The financial results bear conclusive evidence of the value of these local conditions by showing a balance of over 2,500,000 Rx of profit, after interest has been paid on the cost of construction. The most extensive area irrigated in one year was just under 2,000,000 acres.

In the North-West Provinces the irrigated area was of similar extent until the development of the recent famine, when it suddenly expanded to over 3,000,000 acres. It is in these provinces that the famine of 1896-8 has been most severely felt. It has also on previous occasions been afflicted with a full share of similiar visitations, but with a balance to the good of over 1,000,000 Rx of profit on the canal irrigation system, there is ample encouragement for Government to complete the extensions which have been projected, though the results may be more of a humanitarian character than financially successful. Until this sudden expansion in the North-West occurred, Madras had by more than half a million acres the largest area irrigated by canal water of any province in India, but there in that province the great irrigation system in the deltas of the Godaveri, Kistna, Kaveri (Cauvery) rivers are situated, besides other successful systems of minor importance.

The Godaveri scheme, which was ably conceived and executed by General Sir Arthur Cotton, is a most excellent illustration of the vast possibilities of irrigation when carried out under suitable conditions with engineering skill, backed by the necessary capital. An 'anicut,' twelve feet high, was built across a river four miles wide, or 'seven times as wide as the widest part of the Mississippi,' and calculated to discharge a million and a half cubic feet of water per second. In addition to the stones used in the masonry dam, it was claimed that a million tons of stones were thrown into the
low the foundation to support it. The total cost of
ion was £1,300,000, and the annual expenditure
ıtenance is very heavy, but the final result is most
. The gross profit to Government down till the

end of 1894 amounted to the handsome sum of 284 lakhs of rupees; the area of irrigated land has been extended from 150,000 acres to 700,000 acres. A decreasing population of 560,000 has been expanded into one of 2,000,000, and 500 miles of navigable canals have been opened for local traffic, besides 15,000 miles of smaller distributing channels.

The Province of Bengal stands in a sort of intermediate position among the other provinces, both in the amount of irrigation done and in the matter of financial success.

What has been described as the Gangetic Valley, or great alluvial plain of Northern India, falls into the foothills of the Himalaya Mountains and stretches nearly east and west for a distance of over 1000 miles and north and south with a width of from about 200 to 400 miles. By far the largest portion of the area is considerably under the 600 foot level. Surface-water flows in an east by south direction. The western end rests on the margin of the great north-west desert of India, and is more or less arid in both soil and climate. The east and south-east extremity is low-lying and humid, and a comparative abundance of water is found on or near the surface. Surface-water flows a point south of east, but in addition to the visible sacred river of the Ganges, there is another flow of waters traversing this valley in the same direction. It occupies the interstices of the porous strata which underlie the bed of the true river, and not being confined to the narrow channel of the river, it stretches for miles to the north and south. It is from this underground source that the numerous wells, which perforate the centre of the plain, lieing between Benares and Agra, and embracing the greater area of the North-West Provinces, draw their water supply. Towards the east the wells are comparatively shallow, being only 10 feet or more in depth, and the water is raised by the Persian wheel and the common lever water lift; but as the sources of the underground flow are approached to the west and north-west the wells have to be sunk deeper, and it is necessary to employ the leathern bag or 'mohte' with a tongue or spout, which in the old days used to be made of the tanned skin of an elephant's trunk. Though primitive and ancient—worked usually by two bullocks or buffaloes—it is the least costly and the most effective method of raising water from deep wells under prevailing circumstances.

The conditions necessary for well-irrigation are confined to limited areas to be found in Bihar, the Punjab, the North-West Provinces, and sections of Bombay and Madras. Nevertheless the area watered from wells in India is greater than that supplied by Government canals. In most parts of the Punjab the soil water is too far from the surface to be reached by wells. In Central and Southern India a rocky substratum interferes with the work of sinking, and makes the prospect of finding water doubtful. Direct pecuniary assistance rendered by Government in the sinking of wells has not proved financially successful, but the supply of boring apparatus and the encouragement of agricultural loans have had a more promising first experience. In both Madras and the North-West Provinces the number of wells has greatly increased during recent times of scarcity since Government encouragement has been given.

Another means of conserving moisture which has been tried with great success at the Government farm at Allahabad, is levelling the land in small areas and enclosing these with low earth walls to retain the early rains of the monsoon, which are specially rich in combined nitrogen. This leads to rain sinking deeply into the soil in place of flowing away, as the early rains are so liable to do when they fall upon a dry sun-baked surface. When grass is cultivated upon areas treated in this way, a protective covering is provided for the soil which prevents the free escape of moisture during the dry season.

Irrigation in India is undeniably a most important question, and one worthy of every reasonable consideration and support; but although attempted, no case has been made out against the Government for spending, as it has done, greater sums of money upon railway construction than upon irrigation works.*

* The foregoing lecture was delivered at the opening of the class of Agriculture in Edinburgh University, 18th October 1898.

IRRIGATION IN AMERICA.

THE people of the United States of America are credited with the amiable weakness of desiring to own the largest specimen of anything that can be produced. In possessing the greatest area of land now lying in a desert condition of such excellent quality that, with the addition of an artificial supply of water within reach, it would be capable of producing abundant crops, America may fairly claim to be the greatest country in the world. West of the hundredth meridian the rainfall is so deficient on all districts save the mountain ranges that nearly the whole of this area, when man does not come to the assistance of Nature, is either barren or uncertain to a degree which renders cultivation wellnigh as speculative as horse-racing. Though the total area removed from this category by irrigation does not much excceed four million acres, there are tens of millions of acres of rich alluvial soil washed down from the mountains waiting to be provided with irrigation water as the only necessary preliminary to successful cultivation. As the limit of the virgin soils capable o dry cultivation is reached (and it is generally acknowledged that this contingency is within measurable distance), the future development of American agriculture will necessarily be dependent on the extension of irrigation.

The irrigation hitherto practised is mainly that associated with the utilisation of the water of small streams or the tributaries of the larger rivers, which can be diverted for the purpose by a limited number of people at a small capital outlay. The modern system of irrigation in America is merely in its infancy. It began in an unpretentious fashion, the head-works usually being of a temporary and inexpensive character, though they generally entailed a large annual expenditure for maintenance. But recent years have brought about a commendable alteration. Highly qualified engineers are more and more employed in the erection and control of the works, which are undergoing construction on substantial and permanent lines. Some of the engineering triumphs which have recently been achieved in Western America are not surpassed by corresponding works in other parts of the world except in India, where there exist some important differences in circumstances. In India it may be said the land and the water belong to the Government, and the large works demanding engineering supervision are built and controlled by the Government. In America the Government possesses no proprietary interest, and the works are undertaken by individual or by Company enterprise.

The employment of skilled engineers is of modern date (mostly since 1882), and to the Mormons is due the credit 'of being the first Americans to adopt the practice of irrigation as an aid to agriculture.' The Mexicans constructed more than a century ago various 'diversion' works, but we have no knowledge of the methods adopted by the ancient inhabitants who at a remote period occupied the area in which irrigation is indispensable. The most perfect indications of early irrigation works are to be seen in Arizona, and the existence of their extensive remains is recorded as far back as 1542. Cushing has expressed the opinion that between the eighth and ninth centuries certain rich valleys were densely inhabited by a population living by agricultural pursuits. The irrigation of to-day is to some extent indebted to the efforts of the early Spanish missionaries, who were instrumental in introducing Spanish methods into Mexico after the Conquest. In New Mexico, in the rich valley of the Rio Grande, there are many farms which have been irrigated in the rough-and-ready system of the country for over three hundred years. No process of exhaustion has been going on of the kind so frequently demonstrated where clear water is used, as in the Benares Canal in Spain; but on the contrary the soil has been accumulating fertility by receiving deposits of rich mud from the turbid water of the river. This is a parallel to the results obtained by the ancient basin system of Egypt; and when the full capacity of the river is utilised for irrigation purposes it must lead to the creation of much wealth to the country. In America the water finds its way to the land almost exclusively by gravitation. Though windmill pumps are extensively employed to lift well-water for farm stock and for domestic purposes, probably less than one per cent. of the water applied to land is raised by this and all the other common means by which the mechanical powers are brought into service.

The irrigation water which is got by the flow of never-ceasing or perennial streams, usually fed in summer by the melting of snow on the high mountains, is supplemented by the discharges from rivers that flow, periodically or intermittently, from storage dams, which retain flood-waters against the time of scarcity, and from artesian wells and sub-surface or ground water. The two latter sources have not contributed much to the success of irrigation in America—the supply of water from them being too limited. The number of artesian wells in the United States at the census of 1890 was 8097—mostly in the area embracing North and South Dakota, Nebraska, Kansas, Texas, Colorado, and Southern California. Not quite half were used for irrigation purposes, and the land watered did not then far exceed 50,000 acres. The depth of artesian wells in America ranges between 100 and 1000 feet, a different state of matters from that prevailing in Queensland, where depths of 3000 and 4000 feet are of frequent occurence. Experiments on the utilisation of sub-surface or underflow water, especially on the great plains to the east of the Rocky Mountains, have been extremely disappointing. It has been found by cutting trenches to intercept the water percolating through the under strata that the volume is limited and quite insufficient for any extensive system of irrigation. Close to the foothills of the mountains there is a much greater flow of underground water, which is being more and more utilised for irrigation purposes. Great success in the cultivation of fruit in California has been achieved by water derived from this source.

In the Western States the average first cost of bringing water to farm land for irrigation purposes is $8.15 per acre, and the value when the right is sold independently of the land is $26. The average annual expense in keeping the canals and ditches in good order is a little over $1 per acre. All these very moderate figures are likely to increase in connection with larger and more expansive engineering works as it becomes necessary to extend irrigation from districts that are easily supplied to many which present considerable difficulties. A counterbalancing influence is also to be calculated on as population increases, and all the good land under any given irrigation system is taken up. The cost of head-works, which will then command a greater area than at present, will be diminished in terms of the number of acres supplied with water. In California, the greatest irrigation State of all, land values and water values run up to almost fabulous sums when fruit is the product cultivated. Land, including a permanent water right, costing $1000 an acre, will often yield 8 and 10 per cent. interest on the capital invested, and water rentals rise to $10 and even $20 an acre, and leave a satisfactory profit to the fruit grower.

Irrigation is not all plain sailing and profit, however, unless managed with judgment. In a hot climate, where evaporation is active, water must be applied with skill and in moderate quantities, else serious consequences result. When there is deficient drainage and the subsoil water is drawn to the surface to feed evaporation, the soluble alkaline salts present in the soil, and also originally in some waters (the most injurious being soda salts, especially the carbonate), are brought up with it and left on or near the surface as a white powder which is inimical to plant growth. On the heavier classes of soils the carbonates of soda and potash exercise an injurious influence by altering the mechanical condition of the soil so that the clay in it assumes the characteristics of well-worked pottery clay, and a true tilth, so necessary in cultivation, cannot be secured. The most effective deterrent of the accumulation of salts is under-drainage to prevent the water-table rising nearer the surface than about 10 feet. The growth of lucerne, the alfalfa of America, is likewise an important means by which the balance of water circulation in the soil is regulated. Its deep roots find moisture well down in the soil, and its foliage shades the surface from the direct influence of the sun. The value of this most important of all forage plants in the development of the great irrigation areas of Western America is not yet fully realised. But for its influence it is freely admitted that the prosperous Mormon settlements in Utah could never have been established. It produces enormous crops of green fodder, which under irrigation can be cut six or eight times during the season, sufficient to make 8 to 10 tons per acre of hay of the finest quality. All classes of farm stock thrive well on it, in either its natural or its dry state.

The economic use of water is a great irrigation problem, calculated to check the appearance of alkaline salts and to lower the cost of working. The loss of water by 'seepage' from the water channels. is one of the chief difficulties with which the enigineer has to contend in newly-constructed works; but as time goes on the porous sides of the canals and distribution ditches become silted to a considerable extent, and land which has been irrigated for a number of years requires less water than areas which have recently been put under irrigation. Consequently, the tendency to economy is a natural one. Canals which at first permit of the escape of 40 to 50 per cent. of the water entering the head will in a few years lose probably only 20 to 25 per cent. The 'duty' of water, or the ratio between a given quantity of water and the amount of land it will irrigate, is different under varying circumstances. A common unit employed is the 'second-foot,' in terms of which the volume of water discharging per second is stated; and by an 'acre-foot' is meant the amount of water that will cover an acre to the depth of one foot. Within a few years the duty of water in the growth of cereal crops has risen, with more skilful management, from 50 to 60 acres per second-foot to 100 acres in certain deep, light loamy soils, and to 150 acres per second-foot for shallow clayey soils. In the Eastern States, with a rainfall of 4 in. per month and a crop-growing season of four months, the natural supply approximates to 16 in. or 1¼ acre-foot for a crop. The duty given in this case is about 180 acres for each second-foot. At Riverside, where the water is brought to the land in wooden flumes, the duty for surface irrigation rises to 300 acres per second-foot, and, when sub-irrigation from pipes is introduced in orchards, to 500 acres, and in special cases, where a pipe is laid to each tree, even to 1000 acres per second-foot.

With the increase of population America will in time cease to be a food-producing country for the rest of the world; but after that occurs the vast possibilities of development of her agricultural resources through improved systems of irrigation will prevent her for some generations from becoming the extensive consumer of foreign produce which some economists predict for the immediate future. The rise of 30 per cent. in the value of Texas and other Western States cattle which took place last year is an indication that changes may occur rapidly and unexpectedly. The rise was due in part to general improvement of trade in the country, and to some extent to the discovery that cattle are not over plentiful, though at the present values the well-bred young animals from the western ranches are only reckoned at about half the value of corresponding beasts in this country. America cannot run short of an abundant supply of beef for home consumption, though she may, if prices keep up, be unable to send chilled meat and live cattle for slaughter to our shores. As time goes on lucerne will be grown on extensive alluvial areas of the Western States, and vast numbers of cattle will be matured on it.—*Morning Post*, 16th March 1898.

EGYPTIAN IRRIGATION

Egypt, appropriately termed 'the gift of the Nile,' is perhaps the most perfect illustration of a desert transformed into a fertile, garden-like country by means of a rich and abundant water suppply. Red mud, washed by the copious tropical rains from the rich soils of the Abyssinian plateau, is annually brought down during high floods, and deposited as a general purifier and natural fertiliser. The alluvial soil, accumulated from this deposit through thousands of years, reaches in the delta a depth of 33 to 38 feet, with a maximum of 50 feet near Kalyub. The current during high Nile averages three miles an hour, and at low Nile two miles. In Upper Egypt, the narrow southern portion of the country between Cairo and Wady Halfa, in the valley shut in by the barren hills of the African Desert, the primitive basin system of the ancient Egyptians is still practised. The arable land nowhere exceeds a breadth of fourteen miles, and, with the exception of the land watered by the Ibrahimieh Canal, this section of the country is divided by great earth walls or embankments into basins varying from 8000 to 40,000 acres in extent. In August, while the Nile is still rising, red water is admitted to fill the basins to a depth of several feet. The Fellaheen of to-day ought to be thankful, for the increased security of their crops, to the late Lieut.-colonel Justin C. Ross, the second British Inspector-General of Irrigation, who, among the many benefits which he conferred upon Egypt, carried the basin-inlets further up stream, so that even in a year of very low Nile the basins can be properly filled. The water is imprisoned for a period of forty-five to sixty days, long enough to exclude air and light from the surface of the soil to destroy the weeds and to deposit the red-brown earthy matter held in suspension, to manure the land for the succeeding crop. Sowing is usually done on the wet mud as the clear water recedes. The operation of emptying the basins has been much simplified and lessened in annual cost by the substitution of masonry outlets for the cuts in the earth-banks which were wont to be made until a few years ago.

Under the basin system of irrigation there is no means of supplying water to the crop during the period of its growth, and only one crop can be grown annually, against the two or even three crops which may be produced under the canal system, introduced into Lower Egypt by Mehemet Ali, and greatly developed under British engineers since 1882. This area comprises the Nile delta, which spreads out like a fan from Cairo to the Mediterranean, where it reaches a width of 160 miles. Twelve miles to the north of Cairo the Nile bifurcates, and discharges by two outlets; the Rosetta branch inclining slightly to the west, and the Damietta branch slightly to the east of north. Here also the 'Barrage du Nil' was built by Mehemet Ali under the direction of a French engineer, and, twenty years later, was repaired and put into working order by English engineers, with the object of raising the low-water level of the river, so that it might be made then—as in flood time—to feed the three great canals which branch off at this point and form the arterial channels for a complete network of subsidiary canals commanding the fertile parts of the delta. The change of the irrigation system has completely revolutionised the agriculture of Lower Egypt. Cotton, sugar-cane, and rice—tropical or semi-tropical crops requiring to be supplied with water during the period of their growth—have been introduced; and with their successful cultivation and under the blessings of British rule, which has freed the Fellaheen from a condition of slavery, wealth has flowed into the country. The working population are growing rapidly rich; the Exchequer has no difficulty in finding money to pay interest on the debt of nearly £100,000,000 lavishly contracted within the short period of about fifteen years by Khedive Ismail Pasha; and the coffers of the country remain in a most satisfactory state of repletion for other useful purposes. With the increase in the amount of water brought into the irrigation system by the action of the barrage, there ought to have been provided a corresponding increase in the means for its escape, to prevent the numerous evils consequent upon the inevitable infiltration and waterlogging of the lower areas involved when the drainage system is insufficient. The work of drainage did not at first keep pace with the increase of irrigation water brought on to the land, with the result that the underground water came nearer the surface, and led to the increase in the soil of efflorescences of injurious soda salts, and to the extension of the belt of marshy land which lies on the southern borders of the chain of shallow marshy salt lakes for which the northern fringe of the Nile delta is noted.

The injury has been most marked in the vicinity of the land-locked evaporating basin—Mareotis—the surface of which lay at one time eight feet below sea level. This lake has greatly risen since the influx of additional irrigation water, and much of the fertile low-lying land is damaged near the lake, which now stands too high to act as a drainage outlet for it. To cope with the growing difficulty a grant of £250,000 was made in 1897, for special drainage purposes, by the Caisse de la Dette, a Commission composed of the representatives of the Great Powers, which is entrusted with the administration of surplus funds not permitted to be expended through the ordinary machinery of the Exchequer. When the drainage system now in process of formation is completed the full advantage of the British engineers' utilisation of the barrage will be reaped. Among other important arterial drainage works, the drainage water from the higher land falling into Mareotis will be intercepted and thrown into Lake Edku, which opens to the sea. Private enterprise and the Public Works Department may be depended upon to execute the details which will give the special undertaking its full effect. While we congratulate ourselves on the success of our engineering enterprises, and rejoice in performing the minor operations necessary to adjust altered conditions to immediate surroundings, it is well to look ahead at the possible accumulative effects of the new system of canal irrigation, and contrast them with the results which the old basin system achieved. Though the basin system produced only one crop in the year, it kept the land clear of weeds, and maintained the fertility of the soil, thus rendering the practice of manuring unnecessary. In these particulars the canal system is defective without the aid of manure, owing in a great measure to the smaller volume of water used, and to the fact that it goes on to the land considerably clearer,—much of the fine mud depositing in the water channels, and entailing an enormous annual expenditure in keeping them clear. The full effect of the want of the annual mud deposit and the mechanical benefit to the land from the formation of deep cracks during the long summer season of fallow is not yet practically realised, although the necessity for manure applied artificially is well recognised. Much of the cattle manure is dried into cakes for fuel, and although the ash or mineral constituents are carefully collected and added to the manure heap to which the unburnt portion is consigned, the amount available is not sufficient under the intensive system of cultivation which naturally follows. In some districts manure is got from sheep and pigeons, or from the ruin piles of ancient towns and villages, where *sabakh,* containing a considerable amount of nitrate of potash, is dug up and carried on the backs of camels and donkeys to the 'durra' fields. The exhaustion of the ancient supply, and also of the similar deposit of recent times which may be rescued from the sites of existing habitations by digging up their foundations, is within measurable distance, and Egypt will, before long, be driven to meet the important question of the application of concentrated manures, which will tend to reduce the margin of profit from the crop cultivation, if maize, which is the staple food of the people, is to be grown in future in amount similar to that now produced.

The delicate character of the cotton crop, which in pounds sterling, as an article of export, is many times more valuable than all the other crops taken collectively, will not permit of delay in the adoption of means necessary to maintain soil fertility. In a few favoured parts, where a canalised area can be converted for a season, now and then, into an irrigation basin, the question of artificial manuring will be considerably simplified. The extension of the growth of 'barsim,' or Egyptian clover (*Trifolium Alexandrinum*), the great winter forage crop of the country, would, in some degree, make good the loss sustained by the want of the Nile mud deposit. Something may also be done by improving the order of rotations and extending the period which should elapse between two crops of such a soil-exhausting plant as cotton. It is held by some that if maize be dropped out of the rotation and a fallow substituted, the fertility of the soil for the cultivation of cotton would be maintained, but this method could not be generally adopted, except at a serious national sacrifice.

The crop seasons of Egypt are separated into three distinct periods—(1), the summer, or 'Sefi'; (2) the Autumn, or 'Nili' (high Nile); and (3) the winter, or 'Shitawi.' In summer the semi-tropical crops—cotton, sugar, and rice—flourish. The autumn crops are really catch crops, and take only three or four months to come to muturity. In Lower Egypt 'durra shami' (maize), and in Upper Egypt 'durra beledi' (millet, *Sorghum vulgare*) are the most important crops of the kind. During the cold weather of winter the common European grain crops—wheat, barley, and beans—grow best.

For a number of years schemes have been in the air for the construction of a great reservoir, to store a portion of the water which now runs to waste during high Nile, for distribution in the summer period of scarcity, and at last it has been arranged, as all the world knows, that barrages at Assouan and Assiout are, with certain subordinate works, to be built (within five years from 1st July 1898) at a cost of £2,000,000, by Messrs John Aird and Company. In Lord Cromer's report (May 1898) it is stated that 'The Egyptian Government has undertaken to pay for the works by semestrial payments of £78,613 over a period of thirty years, beginning from the 1st July 1903.' But it is also possible to utilise the water in some of the great Central African lakes that feed the Nile, by constructing masonry

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regulators in their strong natural banks, or at their present outflows where more expedient, so that the water surface might be lowered artificially during the dry months for the benefit of Egypt. To lower the surface even slightly would yield an enormous additional supply of water, when we consider the great superficial area of these inland fresh water seas. An additional supply of water will lead to an immense economy of the labour of man and beast employed in raising water during summer from the shrunken Nile stream and from the Lower Egypt canals, which then act as reservoirs, the water falling too low to discharge by gravitation on to the land. Steam pumps have been erected in considerable numbers; but the two primitive Egyptian methods of water-lifting are still very generally in evidence—the 'shaduf' lever-lift or swing-bucket, worked by hand labour, and the 'sakiyeh,' or wooden 'Persian wheel,' fitted with earthenware vessels for buckets, and worked by a bullock or buffalo. Another source of water supply which is about to be tested is that of artesian wells along the low-lying areas near the northern margin of the delta. It is argued that the water percolating through the strata lying underneath the river, being below sea-level, must escape by rising somewhere in the basin of the Mediterranean, and that if shafts be sunk in the delta, the water, in virtue of the pressure behind and the difficulty of its natural means of escape, would rise to the surface and become available for irrigation purposes. With an increased supply of water, especially during the summer, and an improvement of the drainage system of the country, the extent of cultivated land will expand, by encroachment on those areas which are at present covered with marsh or salt lake.

The increase in the capital value and demand for cultivable land which has taken place within recent years will also give the work of reclamation an additional impetus. The soil of these areas is charged with soluble salts to such an extent that no crop plant will grow upon it, and they can only be removed in solution by washing. Such work has been successfully carried out on a considerable scale on the estate of Dranet Pasha at Kafr-ed-Dawar, and in the basin of Lake Aboukir, which was at one time one of the most fertile spots in Egypt, though lying below sea-level. At the siege of Alexandria in

1801 the British cut the narrow neck of land which kept out the sea water and submerged it, and the soil is only now gradually, but surely, being restored to its pristine fertility. Surface washing is found to be of no practical benefit. There is only one way of accomplishing the object in view; that is, by passing successive washings of fresh water through the body of the soil. The land to be treated is laid out in rectangular areas, 300 by 50 mètres, containing about 3½ acres each. On three sides ditches three feet deep and two feet wide at the surface are dug, and retaining banks to hold the water on the land to be treated are constructed, three to four feet wide and six to ten inches high, of the earth excavated from the ditches. Water is brought in at the higher end of the area, and as each charge soaks through and escapes by the drains a new supply is run on—the operation being actively continued from September to May inclusive—one man, with wages of one pound per month, having in charge about 75 acres. In April the seeds of 'dineba,' a native grass which thrives like rice, in six inches of water, is sown, and if the reclamation be complete clover may succeed it in the rotation. After a good crop of clover, cotton will grow, and the work may then be regarded as satisfactory. Heavy land which does not permit the water to pass freely through it may take also a portion of the following season to complete its washing.

The area of Egypt under cultivation is over 6,000,000 acres and the population numbered 9,734,000 in the spring of 1897 as against 6,814,000 in 1882—an increase of 43 per cent. It is stated by one authority that the soil of Egypt at one time supported twenty million inhabitants, but at that time the cultivated area was probably much greater. It is believed that a natural dam which has been broken and worn away existed at the First Cataract, and that the decrease of population was concurrent with the diminution of the available water supply and the shrinkage of the area under cultivation. The trend of circumstances will in future, it is hoped, be in quite a different direction under the just and firm rule which let us trust Egypt will long continue to enjoy. There is not only scope for general development in Egypt proper; the vast capacity for production in the Soudan and the Equatorial

Provinces—happily soon to be restored to the rule of the Khedive, for exploitation by civilised means and enterprise—is not at present capable of being estimated.—*Standard*, 11th April 1898.

ARTESIAN WATER IN AUSTRALIA.

PEOPLE living in humid atmospheres are liable to forget that, among the treasures which mankind are busily engaged in extracting from the bowels of the earth, water is one of the most useful or even indispensable.

In arid regions, which occupy much of the earth's surface, water is diligently searched for, and large sums of money are expended in tapping Nature's vast subterranean reservoirs. In the twisting and contorting of the various strata of which the crust of the earth is composed, the edges of porous rocks, which 'dip' to distances of several thousand feet from the surface, are exposed, and naturally at places where they aid in forming mountain ranges, which attract the clouds and thus secure a copious rainfall. Water entering there by gravitation often travels for many miles underground, protected from the evaporating influence of the sun by its earthy or rocky covering, and remains, in the vast majority of cases, imprisoned until, by artificial boring, it is again led to the surface. Water thus passing through rocks dissolves soluble materials by the way, and becomes charged with alkaline salts in varying proportions. The process is also intensified by the high temperature—almost at boiling point—to which water rises when it descends to depths of 5000 feet to 6000 feet. In some limestone formations underground channels are formed or are widened by flowing water until they assume the dimensions of rivers, in which, as may be witnessed in Southern Europe, America, and South Africa, blind fish are to be found, the progeny of many generations which have existed in total darkness.

Perhaps the most interesting, and in the case of our Australian colonies the most useful, source of sub-surface water is the artesian well. The character of the strata, on which the colony of Queensland, lends itself in a most exceptional manner to the success of artesian well-boring. Lower Cretaceous water-bearing rocks, stretching for several hundred miles without a 'fault' to break their regularity, overlie Palæozoic rocks which form an immence basin in which the Cretaceous strata have been deposited. From Central and Western Queensland this great artesian area has been proved to extend through New South Wales, where it occupies fifteen square degrees of country and passes over the western border into South Australia. Though a considerable advance has been made in the latter colonies in providing water on stock routes and for animals grazing in the semi-arid areas on which salt bush is the staple food of herbivorous animals, by far the greatest developments have been made in Queensland, which, like the rest of our Australian colonies, is visited by disastrous spells of drought.

Within little more than ten years 541 bores have there been sunk, the most important of them ranging from about 1000 feet down to 4438 feet in depth. So expert have the contractors become with the boring plant introduced from America that it is believed a depth of 5000 feet could be reached without difficulty should conditions occur to require it. In the United States, the great pioneer country for extensive artesian well-sinking, there were recorded at the census of 1890 as many as 8097 bores, but the depth only ranged from 100 feet to 1000 feet. In Queensland the most recent and much reduced cost of sinking is 16s. 6d. to 25s. per foot according to depth. The water from many of the deep wells is discharged with great force, as much as 245 lbs. per square inch of static pressure having been registered at the surface. To prevent the wearing of the sides of the bores which is speedily followed by the reduction of the discharge, cast-iron casings are inserted, 2 in., 4 in., 6 in., or 8 in. in diameter, according to the dimensions of the opening; and to prevent the waste of water, which as time goes on and as more wells are sunk, might lead to the reduction of the general supply, caps are adjusted to the discharge pipes by which the flow can be stopped or regulated.

The continuous flow of different wells is very variable, but it runs up in a good many instances and not necessarily in the cases of the deepest wells, to 3,000,000 and 4,000,000 gallons per day. The temperature of the water coming from a depth of 1000 feet or more is generally well over 100° F., and temperatures of 194° and 196° have been recorded. A few wells give out 'sweet water,' which is charged with alkaline salts, to which animals do not object, though plant growth is injured by their presence, especially when carbonate of soda is abundant.

Though it may be salt at first, the water from most of tl large wells becomes, after a time, pure enough for irrigatic purposes, and surplus discharges are beginning to be utilise in this way. Care is now taken to locate the wells on th high ground, so that by gravitation the water can be con ducted in surface channels to the surrounding irrigabl country.

The capabilities of much of Westralia and South Australia have not yet been tested for artesian water, but Victoria is unfortunate in not possessing the geological conditions necessary for an abundant supply of good water from this source. A few bores have been sunk, but where water has been found the general nature of the discharge is alkaline. This colony has, however, been the pioneer colony of Australia in systems of irrigation, supplied by water from other sources than that under discussion, and although in the pecuniary sense the results cannot yet be pronounced quite satisfactory, still ultimate success is now practically assured.—*Field*, Jan. 24, 1898.

IRRIGATION IN THE COLONY OF VICTORIA

It has fallen to the Colony of Victoria to take the lead in developing systems of irrigation which utilise river water, and thus to some extent prevent the unthrifty process which Nature follows—namely, that of draining off the moisture from an arid continent where its value, if properly distributed in the soil, would be immense. A limited area in Australia is sufficiently provided with moisture for the growth of crops.

Some of the rivers which flow inward disappear and are lost in the great central desert, but much of the rain falling upon the great East Coast range, and on other subordinate mountain ranges, finds its way to the sea in river channels, which have been cut deeply into the soil and lie much below the surface of the surrounding country. In order to bring the water up to flow by gravitation into distributing channels is necessary to construct costly masonry weirs at selected tes on the rivers.

This work the colony of Victoria has entered upon with nthusiasm, and it has spent large sums of money for the enefit of a community which did not possess either the ecessary amount of experience in the practice of irrigation o enable it to take full advantage of the opportunities offered, or the amount of faith in its success to induce individuals to give their best efforts to making the venture successful.

The depression in trade, and the financial crisis through which the colonies have passed, have also militated against the triumph of the well-meaning efforts of the Victorian Government. Much of the capital, locked up in the magnificent head works which were erected, has in consequence remained unremunerative; but, encouraged by the necessity for water during recurring years of drought, and by the revival of trade, and of financial and industrial confidence in the colonies generally, slow but steady progress is now being made in the development of the valuable agricultural resources of the colony by means of irrigation, and a few years will probably see Victoria, braced by the difficulties she has encountered, occupy that advanced position to which the sacrifices she has made entitle her. By the Water Act of 1890 Victoria has been freed from the action of the British Riparian laws, which have proved such a bugbear to irrigation in other British colonies and in America. By this Act permission is given for the establishment of waterworks and irrigation trusts, with power to procure and supply water for irrigation and other useful purposes.

Among the national works which have been undertaken by Government, that for the irrigation of the Goulburn Valley occupies a creditable place among the great engineering works of the empire. The complete scheme embraces a weir of solid masonry 925 ft. long over abutments, including 230 ft. of channel regulators; a canal on the east bank 31 miles in length, with a maximum capacity of 20,000 cubic feet of water per minute; and a canal on the west bank 84 miles long to carry 100,000 cubic feet per minute,—the latter to pass through an enormous reservoir at the Waranga swamp, capable of containing 9000 million cubic feet of water. The last annual report of the secretary for water-supply shows that of this work only the river weir and 19¾ miles of the western channel, with regulators, &c., have as yet been completed, at a total expenditure of £447,507. It goes on to say: 'The weir raises the summer level of the river about 45 feet, and provides an available storage of 670 million cubic feet above sill-level of the channel offtakes. The body of the work is of Portland cement concrete, faced on the downstream side with coursed granite blocks in steps, each course being laid upon and notched into that below. The waterway of the weir is occupied by twenty-one flood-gates, each 20 feet horizontal by 10 feet vertical in the clear. For the passage of floods, these gates are lowered into chambers in the body of the structure, so as to be flush with the crest of the masonry.' They are so regulated as to maintain the water impounded by the weir at the raised summer level, 10 feet above the permanent crest. Each gate weighs about seven tons and is worked by screw-gearing, the motive power being obtained from three 30½ inch 'Leffel' turbines.

Hand-gearing is also provided over each gate, to be available in case of emergency or accident to the shafting. An electric lighting plant is provided for convenience of night work during floods. The heaviest floods that have passed over the weir since its completion were those of July 1891, July 1894, on both of which occasions the computed discharge was 1,424,000 cubic feet per minute.

Besides a number of small works, a weir has been erected on the Loddon river at a cost of £85,600, forming a dam with a capacity of 610 million cubic feet; and an intake and regulation have been erected at the head of Gunbower Creek at a total expenditure of £175,297, to turn the water into

Kow Swamp, which is now converted into a reservoir holding 1450 million cubic feet of water available for summer use.

The irrigation colony of Mildura on the southern branch of the Murray river, 340 miles north-west of Melbourne, has been prominently before the British public during the last ten years. Messrs. George and William B. Chaffey, Canadians, who had developed the successful irrigation colony for fruit-growing at Ontario, California, in the corporate capacity of Chaffey Brothers, Limited, entered into a contract with the Victorian Government to lay out and supply with water, to be pumped from the river Murray, 250,000 acres of land in a district of the colony, which, covered with mallee—an inferior description of timber—was lying in a state of Nature. The company undertook to spend £35,000 in the first five years, and during the three succeeding periods of five years the sums of £140,000, £75,000, and £50,000 respectively, or a total of £300,000 within twenty years. The work was begun in October 1887, and 25,000 acres were cleared and laid out in blocks of ten acres each in a similar plan to that adopted so successfully in the fruit-growing irrigation settlements in California, the blocks being sold at from £15 to £20 per acre to settlers who receive the necessary water from the company at the highest points of each holding, and distribute it in their own way and at their own cost within their own boundaries.

Acting under their indenture with the Government, dated May 31, 1887, they had spent on the first 50,000 acres to which they had secured access the sum of £183,000, or more than five times the amount agreed upon to be spent during the first period of five years.

Main canals were cut, 92 ft., 85 ft., 70 ft., 70 ft., 50 ft., and 35 ft. wide, and, in addition to smaller engines, two triple-expansion condensing engines of 1000 i.h.p. each and one of 500 i.h.p. were erected to raise the water into the canals which had been cut at different elevations to command the ground requiring irrigation. Most of this work was accomplished by centrifugal pumps, of which there were employed two of 40 in. and eight of 20 in. in diameter—the largest and most complete pumping plant ever erected for irrigation purposes. On March 10, a license to the company to begin operations on the 200,000 acres, for sections of which titles were to be granted as soon as the company had expended £1 per acre on it in permanent improvements, and paid a fee of £1 per acre into the Colonial Exchequer. A township was laid out and arrangements made for the development of a complete self-contained community, composed of people representing all the ordinary industrial trades and professions. Over 3000 people, including 350 school-children, flocked to Mildura from all parts of the British Empire, and many resident in the colonies invested money by taking up ten acre sections. While the rush lasted money was plentiful and the work of development went on gaily; but the settlers were a mixed lot, many of whom had no knowledge of hand labour or of technical skill in fruit culture, which was the great industry of the colony. Mistakes were made in the selection of the species of trees suitable for certain classes of soils; many inferior and worthless varieties of young fruit trees were sent up and sold to the ignorant people, and the first samples of produce were in many cases extremely disappointing. The distance from Melbourne was great, travelling inconvenient and tedious, and the carriage of produce by rail and river expensive. The price of fruit, owing to the rapid increase in its supply, fell in the colonies, and great difficulty was at first experienced in drying and in shipping it to the English market. The fruit from good trees was of excellent quality, and the soil proved to be admirably suited in texture and composition, as well as in the rolling nature of its surface, for irrigation purposes. The Irrigation Company began on a too ambitious scale, and extended its main canals so far without puddling with clay or lining with cement, that in the newly-broken porous soil more than half the water lifted by the pumps escaped by 'seepage' before it reached the land to be irrigated. The leakage not only led to the waterlogging of certain parts of the lower lying areas and the accumulation of alkaline salts on the surface, to the injury of vegetation, but it seriously increased the annual cost of pumping, and led to a disagreement between the Irrigation Company and the settlers. When the pumping was first started, Chaffey Brothers, Limited, taught the early settlers a bad lesson by supplying free water, and when money became scarce and a rate had to be charged to cover annual outlays, the cultivators rebelled, mistaking the privilege they had enjoyed for a right. Reports of the disputes, which were carried on with more energy than the work of irrigation or cultivation, and of the impending law-suits, soon spread abroad, and the stream of settlers and flow of money to the colony immediately ceased and began to turn in the opposite direction. Chaffey Brothers, Limited, became bankrupt, progress was suspended, and for a time it seemed as if the whole colony on which hundreds of thousands of pounds had been spent would be deserted. After a careful enquiry, which revealed the fact that the combination of soil and climate at Mildura were admirably suited to irrigation purposes, the Government came to the rescue by passing, on December 24, 1895, an Act to constitute irrigation trusts, transferring to them the privileges vested in Chaffey Brothers, Limited, and granting powers to borrow money from Government or otherwise, to line the main canals with cement, and to maintain the pumping plant in good order. Companies have recently been formed for drying and otherwise preserving and shipping the fruit, which is now being produced in rapidly increasing quantities, as the young trees come into bearing; and connections are being formed with the London market which are likely to lead to the development of a profitable trade with Europe, and, as a secondary influence, to steady the prices for the fruit consumed in the colonies.

A number of people who have shown themselves to be wise, at least in their own estimation and after the event, have taken to reprimanding the Victorian Government of the last decade for the extravagant expenditure of public money upon irrigation, and it is not an uncommon practice in the other Australian colonies to point to the lavishness of Victoria in irrigation expenditure as a warning to Progressives to keep down expenses; and it must be admitted, in view of the whole circumstances which are now apparent, that the rate of development was too rapid. The people upon whom the great burden of additional work and responsibility ought to have fallen were ignorant of even the first principles of irrigation, and, in not a few instances, prejudiced against it; and, moreover, Victoria has had to pass through a financial crisis which shook her resources to the foundation — a circumstance which no one could foresee. The results of early blundering and financial and other misfortunes will pass away in time, and the necessity for irrigation and the suitability of local conditions will ultimately assert themselves in the pioneer irrigation colony of Australia.—*Field*, April 9th, 1898.

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