No. 1,555.—“The Drainage, Irrigation, and Cultivation of the Albufera of Alcudia, Majorca; and Application of the Common Reed as a Material for Paper.” By HENRY ROBERT WARING, M. Inst. C.E.

A CONSIDERABLE amount of capital has been invested in the drainage of marshes on the east coast of Spain, hitherto with unsatisfactory returns. This has also been the case with the Albufera of Majorca, an important example from the nature and completeness of its drainage and irrigation works, the large area now reduced to first-class cultivation, and the remarkable improvement which the drainage has effected in the sanitary condition of the adjoining district, the population of which is rapidly increasing.

This marsh was purchased and its drainage undertaken by the Majorca Land Company of London. The total area of the reclaimed land is 5,100 acres. Its northern extremity reaches nearly to the town of Alcudia of 1,500 inhabitants. Sand hills fringing the bay of Alcudia form its boundary for upwards of 5 miles on the east; on the north and south it is bounded by hill farms and pastures, and on the west for a length of 3 miles by the so called “Marjales” of La Puebla and Muro, towns of about 5,000 and 4,000 inhabitants respectively, which are situated 3 miles from the border of the Albufera. The Marjales referred to are low lands now in a high state of cultivation, irrigated by “norias” or by hand, and producing for the most part two crops yearly; their area is upwards of 3,000 acres. The works for the drainage and irrigation of the Albufera have been executed from the designs and under the direction of Mr. J. F. Bateman, F.R.SS. L. & E., President Inst. C.E. They were begun in 1864 and terminated for the most part in 1871. Such works as further experience of the climate and influential torrents showed to be advisable have since been executed under the same direction. The drainage works provide for the carriage through the property and discharge to sea of two of the principal torrents of the island, which rise some leagues away in the mountains 5,000 feet above sea level. These torrents are carried in embanked channels; they form a junction in the Albufera, and flow united to the sea in a watercourse 164 feet wide and nearly 10 feet deep from the top of

the embankments. The outlet to the sea is protected and preserved by two jetties of rockwork carried into deep water.

The copious springs on the borders of the Albufera, the water from the Marjales, and from more local torrents, are also carried in embanked canals and discharge into the main watercourse near the sea through automatic flap-gates. A portion of this water serves for irrigation.

The drainage of local rainfall, and of water derived from filtrations on the property, is effected by four steam engines, one of 40 HP. and three of 25 nominal HP., working scoop wheels. These engines are placed in pairs at stations upwards of 2 miles apart. The largest engine also serves to raise water for irrigation. The drainage water elevated by the scoop wheels finds its way to sea from one station, through the main watercourse, and from the other by an independent embanked channel.

The main irrigation canals constructed of masonry almost surround the property, and feeders and carriers also in masonry are capable of affording irrigation to upwards of one-half of the property; the available supply of good water for this purpose amounts to 65 cubic yards per minute in dry seasons. By the construction of upwards of 30 miles of roads within the Albufera, means of communication have been afforded between all parts of the property and the neighbouring towns, as well as to the harbour of Alcudia.

The surface soil of the Albufera in general consists of decomposed vegetable matter mingled with mud deposited by the periodical inundations to which the Albufera was formerly subject. The depth of this mixture was much greater at the commencement of the works than now, the result of drainage and further decomposition promoted by cultivation having been to reduce its thickness, which is at present from 18 inches to 2 feet. The greater portion of the surface of the Albufera has subsided, from the causes mentioned, from 18 inches to 2 feet since 1868.

The subsoil is mostly a whitish mixture of calcareous and argillaceous deposit, which, owing to the diminution in the thickness of the layer of vegetable soil, can now be mixed with the latter by deep delving. The layer of vegetable soil is wanting over an area of a few hundred acres, the sites of former lagoons. There are also a few hundred acres of poor sandy soil, some small patches of flat rock of recent formation, and former sand hills now transformed into soft rock; but all these classes form a very small portion of the Albufera.

As early as 1865, while the drainage was yet incomplete, the

cultivation of cotton was attempted by the Majorca Land Company, principally in the sandy districts and on the borders, where the ground was sufficiently firm to allow of steam cultivation. A small quantity of cotton of excellent quality was produced, but the situation open to the north-east and east was too exposed to the violent winds from these quarters to allow of the plant being cultivated with success. The idea was therefore abandoned, and the land thus prepared was let to tenants who merely took advantage of the cultivation bestowed on it by the Company, soon leaving it in an unproductive condition. This land was firm but poor, allowing of ploughing, but requiring much manure.

In 1868, the drainage being sufficiently completed to permit cultivation on a large scale, a system of subvention recommended by intelligent natives was adopted by the Company with the view of attracting labour and capital. This system, which then appeared likely to place the property in a paying condition as soon as possible, was as follows:—

The tenant engaged to delve the surface of his entire holding to a depth of 1 foot 4 inches, to break the clods, and burn, and perform, in fine, all the labours of first-class cultivation as practised in the neighbouring Marjales. In return the tenant was to receive from the Company £2 7s. per acre, and was to occupy the land for two years free of rent.

Almost the whole property was cultivated on this system between 1868 and 1872, and fine crops of oats, the only crop at that time thought possible by the tenants, were produced. But the tenants were speculators, too few in number, and holding areas far too large for their means. They consequently were unable or unwilling to risk the expense of further cultivation, which indeed could never be repaid by successive crops of oats alone, and for the most part they gave up their lands on the expiration of the term of free rental or soon after, and few good permanent tenants have been obtained by this system.

In 1871 the total number of tenants paying rent in cash or in kind was sixty-six; the total corresponding area of land under cultivation was 1,444 acres, and the average area per tenant 21·87 acres.

In 1872 the area paying rent was much increased by the termination of many free leases. The number of tenants was one hundred and seventy-two, the corresponding area 2,467 acres, and the average area per tenant 14·34 acres. Oats still remained almost the only product, as the tenants were unwilling to risk the expense of cultivation necessary for more valuable crops. The

condition of almost the whole area nominally cultivated was lamentable, the purely superficial cultivation which it was receiving having served to foster the growth of weeds, especially of the common reed, which overpowered the crops of 1873.

In this year the Company recognised the advisability of proving at its own expense that the land was capable of producing more valuable crops than oats; that methods which allowed speculators to gain by the labour of others were not advisable; and that tenants should be obtained, if possible, for areas so small as to be cultivable by themselves and their own families, in a similar manner to that which obtains on the Marjales, the quantity and quality of work done under such circumstances being much superior to that of hired labour. No help was to be expected from the immigration of tenants from beyond the limits of the towns of La Puebla, Muro, and Alcudia.

The inhabitants of the island in general are unaccustomed to hand delving, and unable to use the tool employed for this purpose by the men of La Puebla and Muro; besides which throughout the island the demand for agricultural labour is equal to the supply.

It must be observed that the yielding nature of the soil, and the proximity and number of drains, render steam cultivation or even deep ploughing impossible over the greater part of the property, and that the rapid and unceasing growth of the common reed renders the production of permanent grasses out of the question for years to come, while vastly increasing the amount of labour necessary on these lands, thus limiting considerably the area cultivable by each tenant.

In 1873, the subvention system having failed in procuring suitable tenants, the Company commenced cultivation on its own account in a thorough manner for hemp and beans especially; at the same time new tenants were only admitted for small holdings, and for leases of six years.

The result of the Company's crop of beans and hemp in 1874 was such as to change completely the opinions of the tenants, and to induce a considerable influx of new tenants for small areas, with the avowed purpose of cultivating the land for hemp. From this time the number of tenants has continued steadily to increase, and the class of cultivation to improve, the rotation generally followed being a threefold course—hemp, beans, and oats or barley—the last being sown instead of wheat, which as yet does not thrive upon the Albufera. The area under cultivation decreased from 1872 to 1876, when it was at a minimum; since then it has

increased. The average area occupied per tenant has probably now reached a minimum. For the year 1877 the total number of tenants paying rent in cash or in kind was four hundred and eighty-three, cultivating 857 acres of land, the average area per tenant being 1.77 acre. It now seems that most of the surplus labour of La Puebla flows into the Albufera in the shape of tenants or sub-tenants, the former being permitted to sub-let portions of their holdings on the same terms as they themselves hold them. Comparatively few tenants come from either Muro or Alcudia, and the tenants from Alcudia are only fit for cultivating with the plough on the poorer lands.

The construction of two villages has been commenced by the Company with the view of attracting settlers from the more distant towns of Pollensa and Bugar, 7 and 5 miles respectively from the border of the Albufera, and from which a small number of tenants are derived. The population of Pollensa is nearly 9,000, and its parish so small in proportion to the population that a large part of the parish of Alcudia is rented and cultivated by Pollensinos.

Even under favourable circumstances, much time will be required to develop to its full extent the property of the Albufera. Supposing the average area of land cultivated per tenant be ultimately $3\frac{1}{2}$ acres for the vegetable soils, and allowing for a larger area for the poorer lands, the number of tenants requisite to cultivate the whole available area would not be less than twelve hundred, representing a purely agricultural population of between five thousand and six thousand souls. This expansion could not take place until the reeds were in a great measure exterminated; but although this is being effected by good cultivation and hemp crops, it will take a long time to obtain the twelve hundred tenants. If in the meantime any profitable application can be made of the reed, *Phragmitis communis*, which grows so luxuriantly over thousands of acres, it would perhaps be better policy to limit the area under cultivation. The reed mentioned has hitherto served either as forage for cattle when very young, or for burning land in the "Marjales" when at maturity. Several thousand tons of it have been yearly extracted from the Albufera for the latter purpose.

It occurred to the Author that this plant might contain a fibre suitable for making paper. After some preliminary experiments by persons acquainted with the paper manufacture, who augured favourably, in October 1877 trials of the whole process of paper-making with this reed were carried out under the direction of an experienced Belgian paper-maker.

Two separate trials were made with reeds in different stages of growth and dryness as follow :—

TRIAL 1.

Reeds cut before maturity, two months previous to trial thoroughly dry, broken in hemp-scutching machine, and boiled for eight hours with 15 per cent. weight of caustic soda, in a rotative boiler, with 60 lbs. pressure of steam per inch	lbs.
Resulting fibre worked into paper at a rag paper mill as for foolscap and cigarette paper—	950
Result—Paper	lbs. 439
Dry pulp	6
	445

$$\text{Yield} = \frac{445}{950} = 46.84 \text{ per cent. of the raw material.}$$

TRIAL 2.

Reeds cut quite mature and passed immediately through a straw-cutting machine, without drying, and boiled forthwith as in Trial 1, then worked up in same rag mill as for foolscap.	Raw material	720
Resulting weight of paper	lbs.	183
" " dry pulp	40	
	Yield =	223

$$\text{Yield} = \frac{223}{720} = 30.97 \text{ per cent. of the raw material.}$$

The quantity of water contained in the reeds submitted to the last trial must have been very large. Attempts to bleach the pulp were unsuccessful in the first trial, and only partially successful in the second ; the pulp was too much diluted. Subsequently the fibre has been bleached perfectly. Specks in all the samples are pieces of the outside fibre (not knots) which have resisted the disintegrating action of the cylinders used for tearing rags, and show that a different class of machinery is required for making fine papers from this new material. The strength of the paper made entirely from this fibre is very great, and the fibre is particularly fine and elastic.

The Author is unable to compare the cost of the manufacture of reed paper with that of straw or esparto paper, but the quantity of raw material is so great that a manufactory producing 3,000 tons of paper yearly would certainly not exhaust the supply of the Albufera. Good roads and navigable canals intersect the reed

producing district, and connect it with the harbour of Alcudia. The cost of 1 ton of dry reed delivered at any spot on the Albufera would not exceed 8 shillings; and it could probably be delivered in an English port for £4. Should the proposed application of the reed be successful, the necessities of financial enterprise may after all be found to harmonise with the requirements of humanity in the drainage of the pestilential marshes of the Mediterranean.