

Department of Agriculture, Bombay.

BULLETIN No. 54 OF 1912



A NOTE ON STEAM PLOUGHING

BY

A. A. MUSTO, P. W. D.,
Agricultural Engineer, Bombay Presidency.



BOMBAY

PRINTED AT THE GOVERNMENT CENTRAL PRESS
1913

[Price—10a. or 11d.]

**OFFICIAL AGENTS FOR THE SALE OF INDIAN OFFICIAL
PUBLICATIONS.**

In England.

Constable & Co., 10, Orange Street, Leicester Square, W. C.
London.
Grindlay & Co., 54, Parliament Street, S. W., London.
Henry S. King & Co., 65, Cornhill, E. C., London.
P. S. King & Son, 2 & 4, Great Smith Street, Westminster, S. W.,
London.
Kegan Paul, Trench, Trübner & Co., 68 74, Carter Lane, E. C.,
London.
B. Quaritch, 11, Grafton Street, New Bond Street, W., London.
T. Fisher Unwin, 1, Adelphi Terrace, London, W. C.
W. Thacker & Co., 2, Creed Lane, London, E. C.
Luzac & Co., 46, Great Russel Street, London, W. C.
B. H. Blackwell, 50 & 51, Broad Street, Oxford.
Deighton Bell & Co., Cambridge.

On the Continent.

Friedlander & Sohn, 11, Carlstrasse, Berlin.
Otto Harrassowitz, Leipzig.
Karl W. Hiersemann, Leipzig.
Ernest Leroux, 28, Rué Bonaparte, Paris.
Martinus Nijhoff, The Hague.

In India.

Higginbotham & Co., Madras.
V. Kalyanarama Iyer & Co., Madras.
P. R. Rama Iyar & Co., Madras.
Thacker, Spink & Co., Calcutta.
W. Newman & Co., Calcutta.
S. K. Lahiri & Co., Calcutta.
R. Cambray & Co., Calcutta.
Thacker & Co. (Ld.), Bombay.
A. J. Combridge & Co., Bombay.
Superintendent, Government Central Press, Bombay.
D. B. Taraporevala, Sons & Co., Bombay.
Sunder Pandurang, Bookseller, etc., Bombay.
Gopal Narayan & Co., Booksellers, etc., Bombay.
N. M. Tripathi & Co., Booksellers, etc., Bombay.
Mrs. Radhabai Atmaram Sagoon, Bookseller, etc., Bombay.
Ramchandra Govind & Son, Booksellers, etc., Bombay.
N. B. Mathur, N. K. H. Press, Allahabad.

Department of Agriculture, Bombay.

BULLETIN No. 54 OF 1912.



A NOTE ON STEAM PLOUGHING

BY

A. A. MUSTO, P. W. D.,
Agricultural Engineer, Bombay Presidency.



BOMBAY

PRINTED AT THE GOVERNMENT CENTRAL PRESS
1918

INDEX OF CONTENTS.

SECTION I.—THE CASE FOR STEAM PLOUGHING.

	<i>Page.</i>
1 <i>Introduction</i>	1
1a <i>Explanation of systems of ploughing: with sketches</i> ...	2
2 <i>Favourable conditions for power ploughing</i>	11
3 <i>Reasons for a Government Demonstration</i>	11
4 <i>Cultivation of land in Bombay Presidency</i>	12
The various kinds of work for which steam tackles could be usefully employed ... ..	...
5 <i>The eradication of hariali grass and the cleaning of land...</i>	13
6 <i>Secondary operations after ploughing</i>	15
7 <i>Comparison of Sugar Cultivation in India and in the Hawaiian Islands</i>	16
8 <i>Investigations by the writer in India and England</i>	16
9 <i>Plants inspected in England with particulars...</i>	17
10 <i>Ploughing in Germany</i>	17
11 <i>Steam plants now at work in India</i>	18
12 <i>Steam plant being purchased by Punjab Government</i>	20
13 <i>General Remarks</i>	21

SECTION II.—THE MACHINERY.

SELECTION OF POWER.

1 <i>Oil motors versus steam engines</i>	22
2 <i>Explanation of estimates of capital cost and of work done per day</i>	22
3 <i>Explanation of estimates of working expenses and working season assumed</i>	23
4 <i>Abstract of Estimates showing comparative capital cost, and cost per acre ploughed, for each system, with plants capable of ploughing 1,000 acres per season</i>	24

SECTION III.

ESTIMATES.

1 <i>System No. 1.—Direct Traction System.</i>	
a. Conditions under which suitable	26
b. Advantages over other systems	26
c. Disadvantages as compared with other systems	27

A NOTE ON STEAM PLOUGHING

by

A. A. MUSTO, P. W. D.,
Agricultural Engineer to Government, Bombay.

SECTION I.

INTRODUCTION.

1. (a) In writing the following note on ploughing tackles, an endeavour has been made to state the general case in favour of their adoption in Bombay Presidency.

(b) Also to state the particulars of each system so that they may be compared, and that it will be possible for interested parties with little knowledge of these tackles to find which sort of tackle is most likely to suit their conditions. The subject is a complex one, varying not only with the style of plant adopted, but with all the many factors which go to form the conditions of working.

(c) The estimates and statements of advantages and disadvantages of each system are therefore necessarily only approximations, but they have been carefully considered and calculated, and are sufficiently accurate for purposes of comparison.

(d) I have tried to give answers to all the queries put to me by enquirers in the past and to anticipate other points which are likely to arise.

(e) It is not claimed that the opinions expressed are proved and positive facts.

They are merely the expressions of the writer's own convictions, formed after two years of careful consideration and investigation of all the facts within his reach in India and England, and after receiving the opinions of people with many years of practical experience in the working of power ploughing plants.

(f) All the estimates are based on figures supplied by Messrs. J. Fowler & Co., Ltd., of Leeds and Bombay, who are the oldest established and biggest firm manufacturing all such plants.

(g) Other firms have also been consulted, but I should prefer to deal with Messrs. Fowler, not only because they have longer experience, and make more varieties of implements than other firms, but also, and chiefly, because they have a branch in Bombay with expert men of long experience in charge, and are thus able to deal with all matters on the spot.

(h) I believe they are the only firm of steam plough and implement manufacturers with a direct branch in India.

(i) This very important subject of steam ploughing is beginning to excite a good deal of interest in India generally, and in this Presidency; and in the last two years I have received enquiries, and requests for estimates, from eleven large land owners who are considering the purchase of plants: but enormous areas need ploughing, which belong to cultivators whose holdings are too small for the individual owners to be able to contemplate the purchase of these expensive tackles.

EXPLANATION OF SYSTEMS OF PLOUGHING.

1. (a) In order to make the note intelligible to those with no previous knowledge of the subject, it is necessary to explain briefly the various systems on which power ploughing is done.

They may be classified in five principal systems as under:—

Page 3.	—System I.—Direct traction implements.
„ 4	II.—Direct cable drawn implements on the double engine system.
„ 6	III.—Indirect cable drawn implements on the round-about system with traction engine fitted with winding drums.
„ 9	IV.—Indirect cable drawn implements but with portable engine driving separate windlass.
„ 10	V.—Direct cable drawn implements worked with bullock geared windlasses.

A brief description and a sketch of each system is given.

Description of System No. I—Direct Traction.

This is the simplest (but not the most efficient) system of all.

The plant consists only of one ordinary traction engine with wide driving wheels and the plough or other implement to be used.

The engine propels itself to the field to be ploughed, the plough is attached by strong chains behind the engine, and it then works backwards and forwards across the field drawing the plough behind it.

At the end of the furrow the engine is steered round and returns across the field ploughing another furrow.

Or in some cases the engine goes round and round in ever increasing circles starting at the centre of the field.

Thus in all cases the engine has to travel over every foot of land ploughed.

No sketch is necessary to explain this.

Description of System No. II—Double Engine System.

This is the best and most efficient system in almost all conditions.

The plant consists of two similar self-moving ploughing engines, each fitted with special powerful winding drums, on which are coiled strong steel cables.

The plough used is a double ended implement with two sets of plough-shares, for working in either direction. When working in one direction the plough-shares for use in the other direction are raised up clear of the ground.

When the plough reaches the end of the furrows these shares are lowered automatically to the ground and the others, which had been working, are at the same time raised out of the ground.

The plough can then be pulled back in the opposite direction ploughing the next furrow.

These ploughs are known as balance (or anti-balance) ploughs.

To work the plough one engine moves to a headland on one side of the field, and the other engine to another headland on the opposite side of the field, the two engines stopping opposite one another, at any distance apart up to about 400 to 600 yards or less.

The cable from one engine is attached to one end of the plough, and the cable of the other engine to the other end of the plough.

On starting work the plough will be near one engine and 400 yards away from the other.

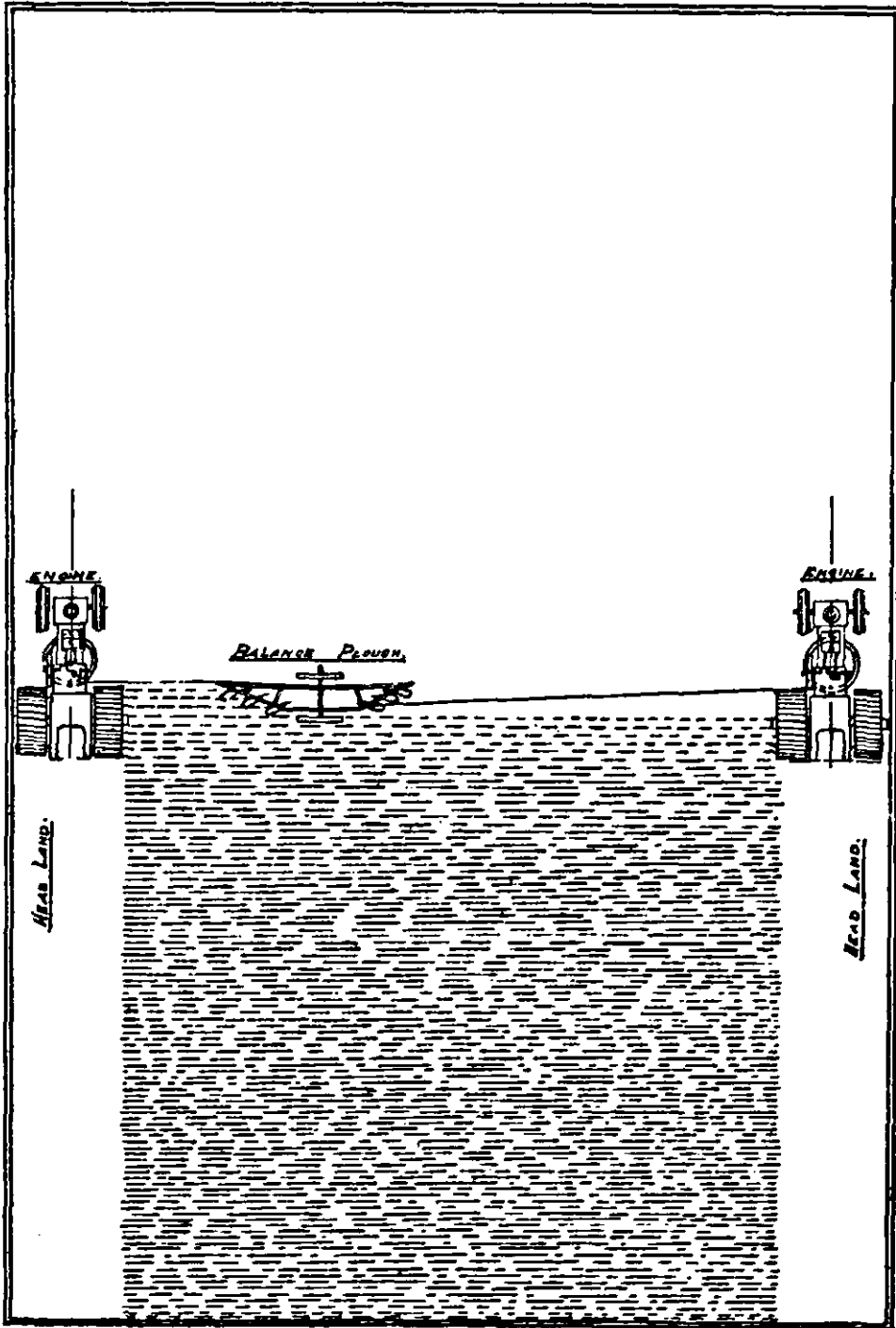
The distant engine begins to haul in its cable thus drawing the plough towards it, the other engine at the same time allowing its cable to be drawn off the drum by the plough.

When the plough reaches the distant engine, the latter stops winding the cable and the other engine begins to pull.

This reverses the plough as explained and it is steered by the ploughman into the next furrow (or set of furrows) as the other engine begins to pull. While one engine is pulling, the other engine (which is paying out rope) moves forward on the headland to the required position for the next furrows, so that the pull on the plough is always in a straight line.

SYSTEM N^o. II.

DOUBLE ENGINE SYSTEM.



Reduced to Scale from a Drawing
Gov^t Photodup. Office Poona, 1912.

Alkumbh.
AGRICULTURAL ENGINEER.
BOMBAY, POONA.

This is the whole system of working and is perfectly simple.

The sketch attached illustrates it.

When the field is completed the engines move to opposite ends of the *same* headland and plough both headlands in this manner before leaving the work.

On shifting to another field the cables are disconnected from the plough, one engine draws the plough behind it (on road wheels) and moves to the new headland, the other engine also going to its new headland.

As soon as the cables are again hooked on to the plough they are ready to commence work.

Thus no time is wasted and the engines do not have to travel over the land to be ploughed but remain on the headlands.

Description of System No. III.—Round-about system with one traction engine fitted with double winding drums.

This is the next best system to the Double Engine system where deep ploughing is needed.

The plant consists of one self-moving ploughing engine fitted with special powerful double winding drums, on which are coiled strong steel cables. The drums when working wind the ropes in opposite directions, that is to say, one rope is being hauled in, while the other is being payed out.

The plough used is a balance (or anti-balance) plough for working in either direction, similar to that described in System II.

In addition to this there is a heavy self-moving automatic anchor. (System IIIa) or two of these anchors (System IIIb). See sketches.

Also one fixed corner anchor, and a number of rope porters or guides.

The method of working is as follows : —

System IIIa.—Triangular Arrangement. (See Sketch IIIa).

The engine moves on to one end of a headland, the movable anchor having first been moved either by the engine or by cattle to an opposite position on the other headland.

The fixed corner anchor is taken and fixed at the other end of the headland on which the movable anchor is fixed.

The longer of the two cables is now unwound from the engine and is carried round the pulleys of the fixed anchor and the movable anchor, and fastened to one end of the plough.

The other cable is then fastened direct to the other end of the plough.

At starting, the plough will be near the engine.

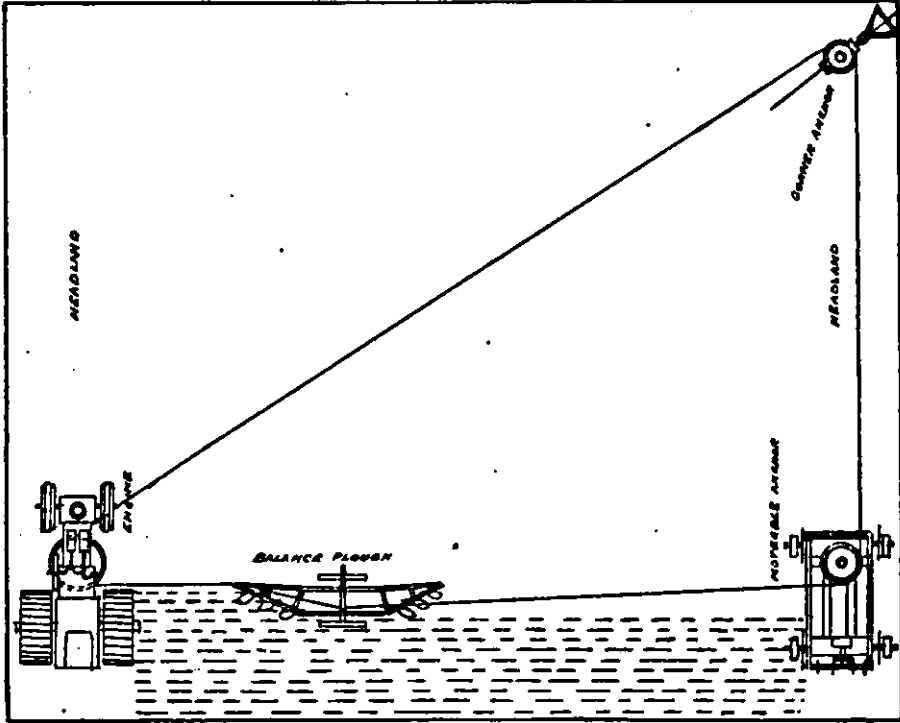
The engine, therefore, begins to haul on the long cable which goes round the anchors, at the same time paying out the short cable.

This draws the plough away from the engine and towards the movable anchor.

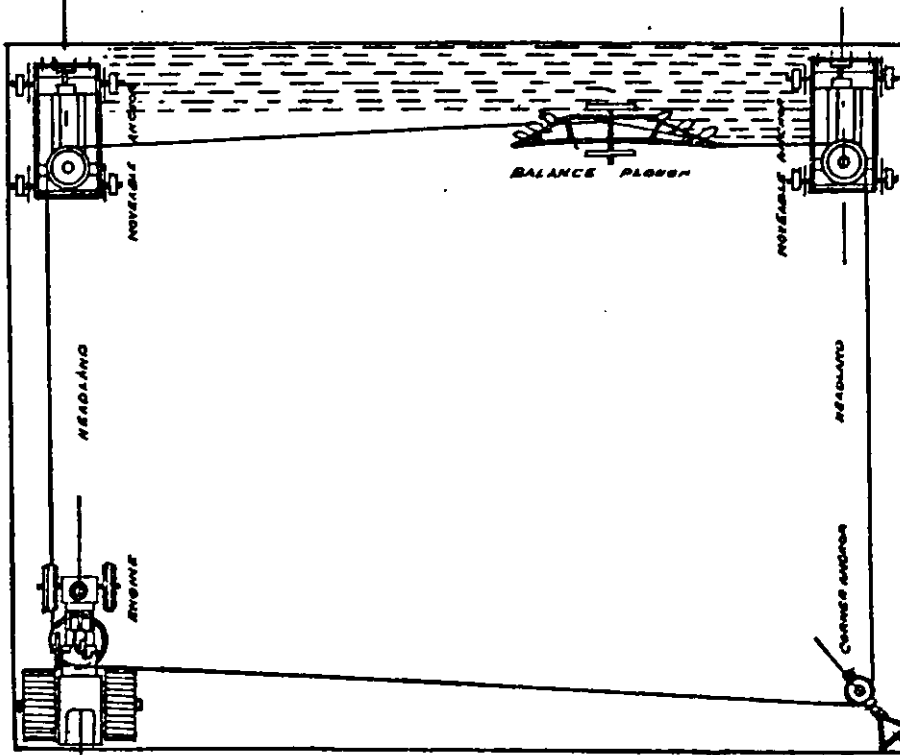
SYSTEM No. III

ROUND ABOUT SYSTEM WITH DOUBLE DRUM TRACTION ENGINE.

TRIANGULAR ARRANGEMENT. A.



RECTANGULAR ARRANGEMENT. B.



Reduced to Scale from a Tracing
Gov. Photodup. Office, Poona, 1912.

A. K. Kulkarni
AGRICULTURAL ENGINEER
A.P.

The movable anchor rests on wheels having deep discs which sink into the ground and offer the necessary resistance to the pull of the rope, and is fitted with tynes which prevent any movement along the headland until they are lifted by the rope.

As soon as the plough reaches this anchor, the tynes are automatically lifted, and as long as the engine continues to pull on the rope, the anchor will move sideways along the headland.

If the headland is crooked the anchor will need a man to steer it.

The anchor having now moved into position for the next but one furrow, the engine ceases to haul, moves forward opposite the next furrow, the gearing is reversed, and the engine again begins to work, this time hauling on the short rope and paying out the long one.

This reverses the action of the plough and draws it towards the engine.

Having reached the engine, the latter is again stopped, the plough is reversed, the engine reversed and hauling is resumed on the long rope, as at first, the ploughman steering so as to make a straight furrow in a direct line to the anchor.

This is the whole cycle of operations. When engine and anchor have reached the far end of their headlands, that is, as far as the fixed corner anchor, the tackle has then to be shifted and the fixed and movable anchors set in another position for the next field.

The system is, of course, much more troublesome than the double engine system.

System No. IIIb.—Rectangular Arrangement.

(See Sketch IIIb).

This is another method of arranging the tackle, by means of which the engine need not move along the headland at all, but remains stationary in the corner of the field.

Two movable anchors are used, set opposite one another on each headland.

The engine stops at the other end of one headland, and the fixed corner anchor at the other end of the other headland.

The long cable now passes round the corner anchor and one movable anchor and is attached to one end of the plough.

The short rope passes round the other movable anchor and is attached to the other end of the plough.

By working the winding drums in alternate opposite directions, the plough is pulled to and fro between the two movable anchors, which move automatically as explained at the completion of each furrow.

I cannot see any advantage in this arrangement, and it requires two movable anchors, instead of only one, and a longer cable.

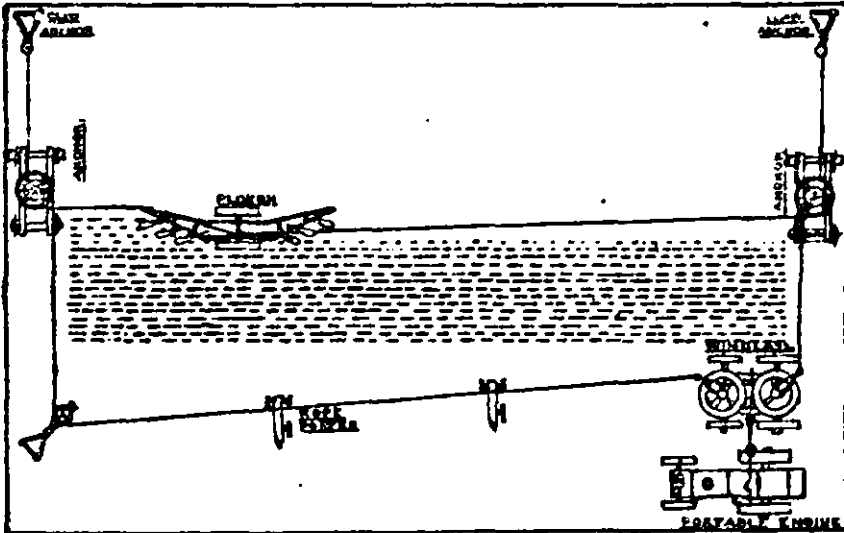
Also the pull on the plough is always indirect.

With either the triangular or rectangular arrangement of this system it is difficult and slow work to plough the headland after the completion of the field.

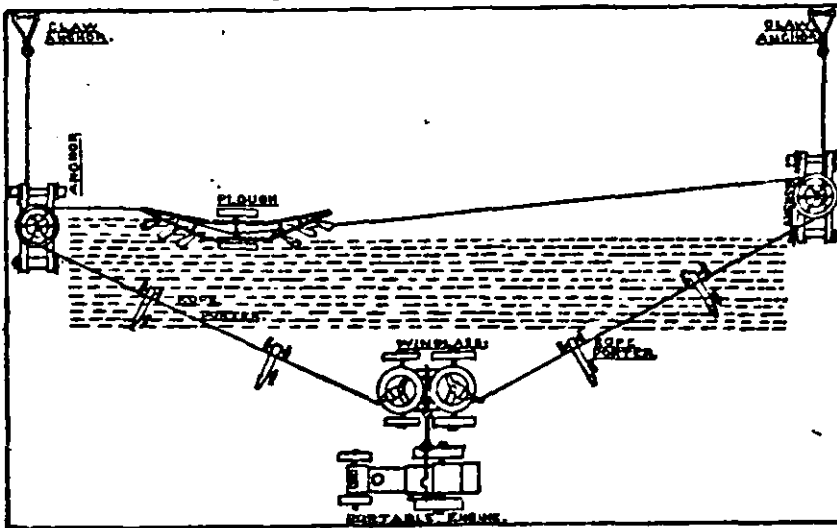
SYSTEM No. IV

ROUND ABOUT TACKLE WITH PORTABLE ENGINE AND SEPARATE WINDLASS.

ARRANGEMENT A.



ARRANGEMENT B.



Reduced to Scale from a Treaty.
Gov. Phoswanco Office, Poona, 1912

Alkumbh.
AGRICULTURAL ENGINEER,
Bombay Poona.

*Description of System No. IV.—Round-about system with
Portable engine and separate windlass.*

In this system all the machinery has to be hauled into position for work by cattle.

The plant consists of one ordinary portable engine, one double drum windlass, two automatic movable anchors, two claw anchors, and one fixed corner anchor with rope porters to support the cable over rises in the ground.

The plant works with the same cycle of operations as the rectangular arrangement of System No. III.

The double drum windlass is connected to the engine in one of two methods, namely, either by a universal driving joint or by pulleys and belts.

If the former method is used the engine and windlass need not be set in very careful alignment with one another, as the universal joint allows for inaccuracy, but on the other hand results in heavy waste of power, and strain and wear on the joints. If a belt and pulleys are used for driving the windlass, the engine and windlass must be set in accurate alignment and level with one another, and at exactly the right distance apart.

Otherwise the belt will run off the pulleys and will slip.

To do this accurate setting in soft land would be a very lengthy and almost impossible task.

Also the weight of the engine, windlass, and movable anchors is great and it would be very difficult to shift them with cattle.

Cannot be recommended.

System No. V.—Bullock gear windlass system.

The plant consists of two similar windlasses, each fitted with gearing and poles for working with two pairs of bullocks.

Each windlass runs on a short section of rails on the headland.

A stout steel cable is wound on each windlass.

The windlasses are placed on opposite headlands and the cable of each is attached to one end of a balance plough, which is drawn to and fro between the windlasses in the same way as on the double engine system.

While one windlass is pulling the other is running free and allowing the cable to be drawn off it by the plough, as the pulling windlass draws it towards the other side of the field.

When the plough reaches one windlass, the plough is reversed and the other windlass begins to pull while the first one pays out the rope.

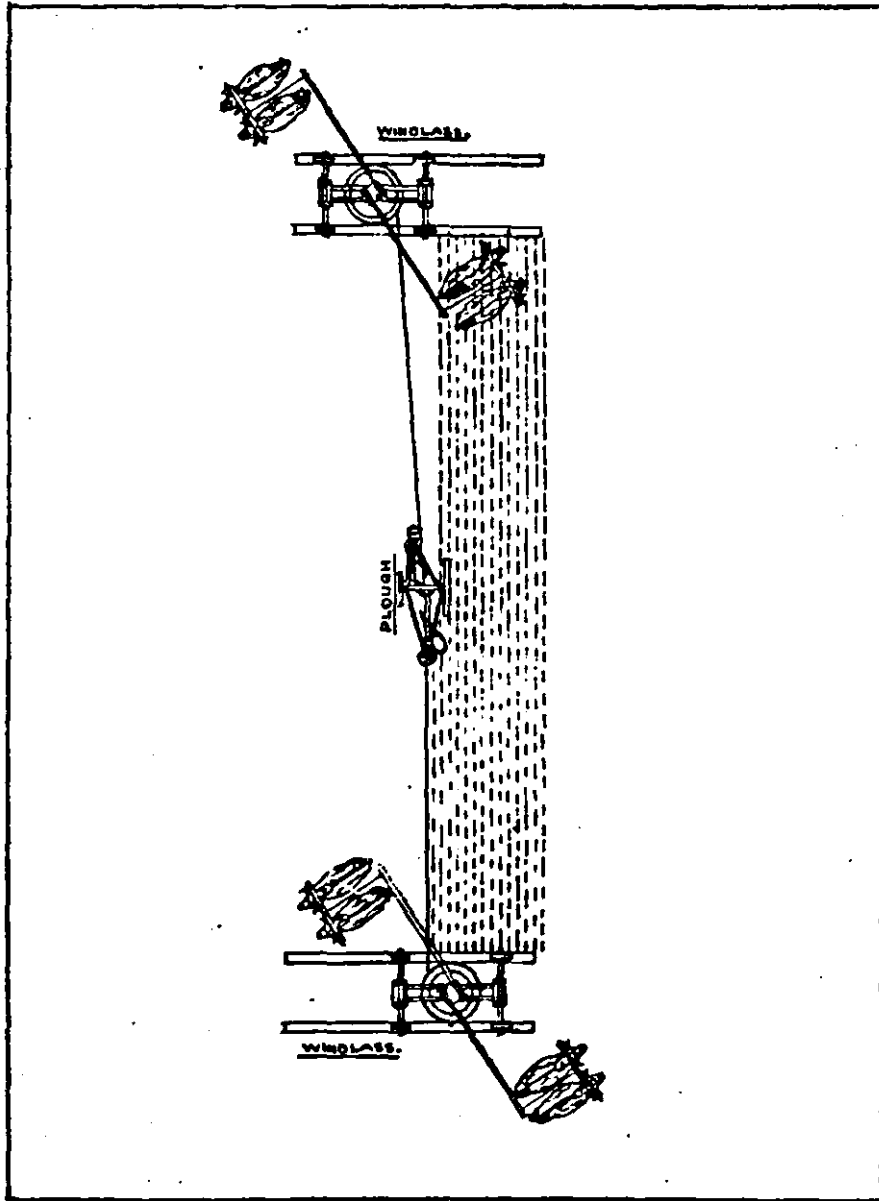
While paying out rope this windlass is moved forwards on its rails into position for ploughing the next return furrow.

The system is as simple and reliable as the double engine system, but is very slow and expensive, as the bullocks of one windlass are always standing idle while the other windlass is pulling.

When it is desired to move to another field, the windlasses are fitted with road wheels and hauled by the bullocks.

SYSTEM No. V

BULLOCK GEARED WINDLASS SYSTEM.



Adkins.

*Reduced to Scale from a Tracing
Govt. Photoduplication Office, Poona, 1912*

AGRICULTURAL ENGINEER.

BOMBAY, POONA

FAVOURABLE CONDITIONS FOR STEAM PLOUGHING.

2. (a) The general conditions under which cultivation by power is desirable may be briefly stated as follows :—

- (1) Where deep ploughing is needed.
- (2) Where large areas have to be dealt with.
- (3) Where secondary operations are needed at once after deep ploughing.
- (4) Where power cultivation is cheaper than other methods or does better work.
- (5) Where cattle or manual labour is insufficient in any case to do the work otherwise.

(b) The successful use of such tackles depends mainly on good business organisation, competent mechanical handling, and supervision, and the collection of charges from the cultivators within a reasonable time.

REASONS FOR A GOVERNMENT DEMONSTRATION.

3. (a) When a plant has once been demonstrated as a paying concern, I do not think that a business company or syndicate will have any difficulty in meeting these difficulties or conditions, but for a private firm to start the initial enterprize would probably be very difficult.

(b) In the case of a Government owned plant the facts would be quite different.

The Agricultural Department has a large trained staff in the mofussil with a thorough knowledge of the districts, and of the land suitable for ploughing.

(c) They also possess considerable influence with the cultivators and a Government owned venture would at once inspire confidence among the people and make them willing to try the innovation.

This has already been proved by the amount of land offered for ploughing in the Ránnibennur Táluka. (See later.)

(d) The Agricultural Engineer, in association with Messrs. Fowler, could supervise the mechanical work and staff, and the collection of charges could be greatly simplified by the advance of tagávi loans to the cultivators to pay for the ploughing.

These loans could be paid direct to the Government ploughing department and thus make certain of payment.

(e) There is thus every essential for the success of a Government owned plant, whereas a private plant would be looked at with suspicion (until proved) and the owners at first would probably have great difficulty in collecting their charges.

(f) If through such difficulties, or through bad management, the first plant purchased proved a failure, it would probably ruin the owners, and, still worse, would almost certainly prevent or postpone for many years any further experiment.

(g) It is for these reasons that I strongly urge the advisability and necessity of the purchase of a demonstration plant by Government.

After proving it successful, I believe there would be no difficulty in disposing of it (if so desired) to private owners.

(h) In support of the latter view I may mention that I am now corresponding with a gentleman in the Kolar Gold Fields, who wishes to do 400 acres of deep ploughing each year, besides secondary operations, and the levelling and terracing of land.

Such an owner would probably be glad to take over a successful plant at a reasonable price. There must be numbers of similar cases.

CULTIVATION OF LAND IN BOMBAY PRESIDENCY.

4. (a) The better cultivation of land is one of the most important subjects claiming the attention of agriculturists in India today.

(b) The very heavy soils met with in so many parts of this Presidency, and the deep cultivation necessary for sugarcane, garden crops, etc., offer almost insuperable difficulties, to the ploughing and subsequent treatment of the land, by cattle drawn implements.

(c) It is also well known that the number of cattle available for such work is much below that necessary to cultivate all the land which might be used to produce such profitable crops.

(d) But perhaps the most important work of all for which power drawn implements could be used, and for which cattle are useless, is the clearing and cleaning of open lands infested with that pest of agriculture—the deep-rooted hariāli grass.

(e) Besides this, these engines will do deep ditching for draining fields, and are capable of making open ditches 3 feet wide and 2 feet deep at a single operation; or mole drains at a depth of 3 feet.

(f) They can also do land levelling by drawing earth with special implements from the high to the low lands, work now done very slowly and laboriously by hand or cattle.

(g) They can also drive threshing machines, cane-crushers, pumps or any machinery when desired, and can draw heavy loads of produce, or timber and materials, to station or market at two or three miles per hour.

(h) Thus on a big estate work could probably be found to keep the engines going almost all the year round, instead of for only six months on ploughing, as shown in estimates.

Every additional day the plant can be worked, reduces the daily proportion of charges for interest and depreciation, which in the estimate amount to 30 per cent. of the total cost of working. The depreciation does not decrease in regular proportion to the days worked, as the plant is depreciating when standing idle for long periods.

THE ERADICATION OF HARIALI GRASS.

5. (a) To eradicate the hariáli grass it is necessary to turn up the soil to a depth of at least 16 inches, and in the heavy soils in which this grass flourishes, it is quite impossible to plough to such a depth with direct cattle drawn implements.

The only way in which the cultivator can rid himself of it at present is by hand digging, an extremely laborious and expensive method.

The cost of this method, when thoroughly done to a depth of 16 inches, amounts to as much as Rs. 75 per acre, and for less effective shallow work to a depth of only 9 or 10 inches comes to about Rs. 40 (forty) per acre. (See page 71, Annual Report of the Dhárwár Agricultural Station for 1910-11.)

(b) There are hundreds of thousands of acres of excellent cultivable soil in the Deccan and Southern Marátha Country, which are rendered quite or almost useless by this hariáli grass.

It will be shown later that it has been carefully estimated that this land could be thoroughly ploughed to a depth of 16 to 18 inches at a cost of about Rs. 15 per acre.

(c) Assuming for the moment that these figures are correct, it can be seen at once from the following figures that enormous advantage would ensue to the owners of such lands.

Large tracts of these hariáli infested lands lie in the Dhárwár, Sholápur and Ahmednagar Districts.

By thoroughly cleaning such lands their value is found to be increased by from 75 per cent. to 100 per cent. according to their condition, locality, etc.

(d) The Deputy Director of Agriculture informs me that in the Dhárwár District alone there are over 600,000 acres of land under cotton, of which more than half is on dirty land infested with hariáli, needing deep ploughing, for which he is convinced the people would willingly pay Rs. 20 to Rs. 30 per acre.

(e) In estimates Nos. IIa and IIb given at the end of this note the double engine plant is shown as being able to plough about 1,000 acres per season.

(f) Thus in the Dhárwár District alone there would be sufficient of this cleaning work only, to keep 15 such sets going for 20 years.

There need be no fear therefore of being unable to find sufficient work for the first experimental set which may be purchased, and already in two villages of the Ránnibennur Táluka 850 acres have been offered for ploughing at a tentative rate of Rs. 20 per acre.

(g) It should be clear from the above remarks and from the estimates to follow, that there is a wide and useful field for the employment of such tackles, and it is generally admitted that any further considerable improvement in the Agricultural conditions of the Presidency, both as regards better cultivation of lands now under cultivation, and particularly bringing into cultivation present waste lands, depends chiefly on the ability to do deeper, more thorough, and quicker preparation of the land.

(h) From the first it was assumed that ploughing to 16 inches depth would successfully eradicate hariáli, but in order to prove this beyond doubt, a demonstration has been made this year at the suggestion of the Director of Agriculture.

A very badly infested area of 13 acres, looking like a grass field, was selected at Dhárwár and was ploughed 14 inches to 16 inches deep with the Bajac plough.

The work was started in January and finished in April and by beginning of April the first part ploughed had weathered down so well that the owner began to cross plough and harrow with country implements in preparation of seeding.

The hariáli was not removed by hand in any way.

A crop of potatoes was sown in June, and in August after some very heavy rain, which rather water-logged other fields, the crop was looking remarkably well, in contrast to the surrounding similar crops which had suffered from insufficient drainage, due to shallow cultivation.

At the same time the hariáli was practically extinct, and the owner is delighted with the results.

Only occasional single blades of grass are to be found and the owner estimates that they can all be removed by hand at a cost of Re. 1 per acre.

SECONDARY OPERATIONS AFTER PLOUGHING.

6. (a) Deep ploughing for sugarcane has already been mentioned.

A very important point to consider in connection with deep ploughing, is the difficulty of conducting further operations to produce good tilth for seed beds on the very rough ploughed land.

(b) For sugarcane cultivation as at present done by indigenous methods, ploughing is done to a depth of not more than 12 to 14 inches and this only with great difficulty and by the use of a large team of bullocks, as many as four or five pairs of bullocks being frequently yoked to one plough. When this has been done the land is allowed to lie fallow for some time, and the weather will break down the heavy clods to a certain extent; but even after this, it is difficult for the bullocks to get across the rough land with the implements for the preparation of the land to take the seed, and such work is very damaging to the animals.

(c) All such secondary operations can be performed with ease by means of the steam tackle, at any time that may be convenient, if necessary, immediately after the ploughing.

COMPARISON OF SUGAR CULTIVATION IN INDIA AND THE
HAWAIIAN ISLANDS.

7. (a) In this connection the following figures recently given to me by Messrs. Fowler are of great interest.

I cannot vouch for these figures, but I do not doubt their approximate accuracy.

The figures for India have been verified.

(b) *Sugarcane cultivation in the Hawaiian Islands—*

Average yield of sugar per acre 4 to 5 tons.

„ ploughing 16 inches deep.

Maximum yield of sugar per acre 15 tons.

„ ploughing 30 inches deep.

(c) *Sugarcane cultivation in India—*

Average yield of sugar (or gul equivalent) per acre
 $1\frac{1}{2}$ ton.

Average ploughing 10 inches deep.

Maximum yield of sugar (or gul equivalent) per acre
(Poona District) $4\frac{1}{2}$ tons.

Maximum ploughing 14 inches deep.

The latter figures are given to me by Mr. Main, Deputy Director of Agriculture.

These comparisons speak for themselves and need no comment to point the lesson.

INVESTIGATION BY THE WRITER IN INDIA AND ENGLAND.

8. (a) I realized the importance of this matter as soon as I first had to consider it, some two years ago, and have done my best to collect reliable information and statistics about it.

(b) When on three months' privilege leave last autumn I spent about five weeks touring round England (at my own cost) to see different ploughing plants at work, and I corresponded with, and interviewed, various owners and makers of these plants to obtain statistics of work done and cost of plants.

PLANTS INSPECTED IN ENGLAND.

9. (a) I inspected plants at work at Leeds (Yorkshire), Gainsborough (Lincoln), Witham (Essex), Reading (Bucks), Chichester, (Sussex), Bosham (Sussex), and Portsmouth (Sussex).

Those seen at Gainsborough and Witham were direct traction oil motor tackles being tested. All the other plants were steam of the double engine system.

(b) I saw ploughing, cultivating, and harrowing operations in progress.

At one estate near Reading the engines were cultivating stubble land of heavy dry soil to a depth of 10 inches with a 13 tyne cultivator covering 8 feet width and travelling at 7 miles per hour.

The land had never previously been ploughed to a greater depth than 8 inches.

After the first operation the fields were again cross-cultivated to break down the clods.

Then after weathering, a light horse harrow would do all that was necessary to prepare an excellent seed bed.

About 40 acres were being done per day of 14 hours and the owner of the plant was making a profitable business by hiring out the plant.

(c) At another place I saw sloping meadow land being broken for cultivation with a 6 furrow plough working to a depth of 6 inches.

This plough was travelling at 4 miles per hour and was ploughing 18 acres per day of 12 hours.

These figures will illustrate the kind of work being done in England by such tackles.

Very little deep ploughing is done in England as the crops grown, and the rainfall obtained, make it unnecessary.

PLOUGHING IN GERMANY.

10. (a) In Germany, however, where a great deal of beet sugar is grown there are some hundreds of sets of tackle at work.

(nearly all of the double engine system) ploughing to depths up to 16 inches.

(b) As an example of what is done there I quote from the report of Fr. Thomas, a steam plough contractor at Dalldorf, Prussia, who gives the following figures for his plant for the year 1908. Working from the middle of August to the end of November, in 86 working days, an area of 2,969 acres was ploughed to a depth of 35 c.m., equal to $13\frac{3}{4}$ inches or an *average* rate of $34\frac{1}{2}$ acres per day. This was in heavy beet land after a season of very severe drought.

The plant was a double engine tackle of the largest size (140 I. H. P.) and was nine years old.

The figures for the previous eight years were as follows :—

1900	from August 20th to November 23rd	— 2,268 acres ploughed.
1901	" " 14th " "	2nd — 1,847 " "
1902	" " 25th " "	17th — 2,019 " "
1903	" " 19th " "	20th — 2,218 " "
1904	" " 15th " "	4th — 1,895 " "
1905	" " 19th " December 29th	— 2,590 " "
1906	" " 17th " "	11th — 2,693 " "
1907	" " 26th " "	13th — 2,498 " "

These figures are most exceptional however and, I believe, are claimed to constitute a record for such work.

STEAM PLANTS NOW AT WORK IN INDIA.

11. (a) Unfortunately very few statistics of actual working results *in India* under similar conditions to those prevailing in this Presidency are available.

I have only heard of three such plants working in India.

(b) One of these is in Behar where it is giving excellent results although the plant is 30 years old and in very bad order.

It is a set of double engine tackle, but the boilers are at present being worked at only 70 lbs. per square inch instead of at 125 lbs. per square inch owing to their having become old and weak. The conditions, however, are quite different to those in this Presidency as the soil of Behar is sandy and the engines are being used only with a cultivator and not for ploughing.

Here however with this very old tackle they are cultivating to a depth of 8 inches and do 15 acres in a nine hours working day.

The crops grown are sugar, indigo, etc.

(c) Another plant was recently in use at Katihar in Eastern Bengal.

This consisted of an old 70 H. P. engine and was being used for ploughing by direct traction.

The results were not very satisfactory and the owners ordered a new set of 80 I. H. P. (K5) double engine tackle (similar to that in estimates II*d* and *e*) for ploughing to a depth of 12 inches in sandy clay or stiffish loam.

This plant has now been at work for a month or two and is giving excellent results as below:—

The plant is ploughing to a depth of 14 inches in land covered with dense grass from 4 to 7 feet high, and in a working day of ten hours with only one set of men, is ploughing $7\frac{1}{2}$ acres per day.

It is expected that these figures will be somewhat exceeded when the men have become more proficient and accustomed to the tackle.

Note.—With the proposed Government plant I have estimated (estimate II*a* and *b*) 8 acres ploughed per day of 14 working hours with two shifts of men to a depth of 16 inches.

(*d*) Another plant was purchased some few years ago by the Gwalior State, but, I understand, has not been very satisfactorily worked.

Unfortunately the State Durbar seems reluctant to give information on the subject, but, so far as I can ascertain, the original plant was a powerful set of double engine tackle.

It was used for drawing a heavy implement known as a 5 tye knifer over very rough unbroken land covered with large stones and tree roots.

The plant seems to have been worked very rashly and was constantly breaking its cables owing to the knifer catching under big roots and the engine not being stopped in time, and also due to the use of cheap ropes.

As they only require to turn up the ground to a depth of about 8 inches and the land is fairly open and level, they have now

purchased another set of engines for direct traction and have been recommended to convert the original set to direct traction.

With this system strong chains can be used to attach the plough to the engine and the engine driver will be able to see whenever he approaches a big root and have time to stop his engine, or the engine would only be pulled up, owing to its wheels being unable to grip sufficiently.

For work of this description under these conditions the direct traction system is the best, particularly with careless management as accidents are less likely.

I understand that with the original plant, when not broken, they were turning up ground covered with roots and stones, to a depth of 11 inches at the rate of 8 acres per day of 9 hours.

STEAM PLANT FOR PUNJAB GOVERNMENT.

12. (a) Another plant is about to be ordered by the Punjab Government for land reclamation work in the Alkaline lands of the Chenab Colony.

It is proposed to do mole draining and ditching with this plant.

As mole drains should only be made in one direction, it has been decided to use only a single engine for the purpose.

This engine will be stationary at one end of the field and draw the plough towards itself with a double purchase cable.

The plough will then be drawn back to the other end of the field by cattle and again pulled forward at the next position by the engine.

The plant consists of—

One K5 Compound engine with winding drums.

One mole draining plough weighing 2 tons.

One ditching plough to make trenches in one operation 2 feet deep, 1 foot wide at bottom, and 3 feet wide at top, weighing 3 tons.

Cost of plant Rs. 21,950.

The Punjab Government has sanctioned Rs. 40,000 for the experiment.

This work could also be done by the proposed Bombay Government plant if desired.

GENERAL REMARKS.

13. (a) Although the statistics available in India are so scanty, there are thousands of sets of these tackles at work in Europe, and the Colonies, and every case investigated shows that very much more work has been actually done, than has been assumed in the estimates below.

The latter have purposely been kept very low, so as to be on the safe side.

It is hoped that Government will arrange to purchase one set of double engine tackle as per estimate No. II and this is recommended primarily for use in the eradication of hariáli in the Dhárwár or Sholápur Tracts.

If many further sets are eventually purchased by Government or by private enterprize, as I am confident they will be, there remain many other directions in which they can be most usefully employed, and where cattle are almost or quite useless.

(b) Granted competent business-like management, I do not think there is the slightest doubt of being able to make a steam plant a very profitable business enterprise, and assuming this view to be correct, it is evident that the benefit to agriculture would be immense.

This is a development of improved methods which, if successful, would at once mark a new epoch in the cultivation of the lands of the Presidency, and the prosperity of its agricultural classes.

SECTION II.—THE MACHINERY.

SELECTION OF POWER.

1. (a) The power for ploughing may be supplied either by a steam engine or a petrol or paraffin engine of the portable or traction type.

(b) Traction engines are almost essential for this work as will be shown later, so that this type only need be considered here.

(c) In Europe and the Colonies—particularly in Canada and also in the United States—the internal combustion motor has found a very considerable opening in this class of work, chiefly owing to local conditions and its cheapness, but for India it cannot be recommended.

(d) The oil-motor traction engine, if kept in thoroughly good order, will do very good work, but the large amount of vibration and dust to which traction engines, used for cultivation, are subjected, tends very quickly to throw the oil-motor out of adjustment, and continual attention is necessary.

Oil traction engines are also much more tricky to handle than steam traction engines, and in India there are very few men capable of running such machines satisfactorily.

(e) The steam traction engine on the other hand has many less parts liable to give trouble, its power is much more elastic, and it is easy to find men in India, trained in the use of steam engines, who could run the engines without difficulty.

CAPITAL COST AND WORK DONE PER DAY.

2. (a) Estimates of cost of plant and of working expenses for each of the first four systems are given, in each case taking engines of the same power, so that a fair comparison may be made. The estimates of cost of plant are approximate only, but are sufficiently accurate for comparison.

The estimates for the bullock geared implements are taken from actual experience with the Bajac plough now being used in the Dhārwar District.

The estimates of area ploughed per day are based as far as possible on figures of actual work done by different ploughing tackles in all parts of the world and, where actual similar conditions are not

available, on the careful estimation of Messrs. J. Fowler & Co. who have had 50 years' experience in making and working such plants.

It is believed that these estimates of area ploughed are in all cases on the safe side and would probably be exceeded in actual work.

WORKING EXPENSES AND SEASON ASSUMED.

3. (a) In estimating yearly working expenses and total acreage ploughed for systems I and II, a working season of six months has been assumed (November to April inclusive), out of which 50 days are allowed for shifting tackle from field to field or village to village, for holidays, and for days when plant may be idle for repairs or other reasons.

This leaves 130 working days per season. The Deputy Director and I have gone into the matter carefully and believe this is a safe estimate, but is not likely to be much exceeded.

(b) For system III a further deduction of 10 days from the working season is made to cover the time which will be spent in collecting the anchors, porters, snatch blocks, etc., and resetting them around the area to be ploughed at the commencement and finish of each area ploughed.

This work would be done by the engine itself for quickness and ease.

(c) For system IV a further deduction of 20 days from the 130 days working season is made to cover the time spent in shifting the portable engine, the heavy windlass, the anchors, porters, and snatch blocks, and resetting them at a fresh area.

All this work must be done by the cattle and would prove almost impossible.

It is extremely doubtful whether the deduction made is sufficient, but as the system is not recommended, the accuracy of the estimate is not of great importance.

(d) For system V a working season of six months is assumed from which a deduction of 30 days only is made for holidays, accidents and shifting tackle, leaving 150 working days.

In this time the tackle will only plough an area of 38 acres so that very little shifting will be needed.

Abstract of Estimates showing comparative Capital cost for plants capable of ploughing 1,000 acres per season, and cost per acre of ploughing, with each system.

System No.	Name of system.	Depth of ploughing.	Proportionate Capital cost for plant to plough 1,000 acres per season.	Cost per acre ploughed.	Remarks.
		Inches.	Rs.	Rs. a. p.	
I	Direct Traction system	16 to 18	.....	.....	Not possible to plough to this depth by this system. For shallow ploughing see bottom of page (other side).
II	Double Engine system	"	39,000	14 8 0	The simplest, quickest and most efficient system under almost all conditions.
III.	Round-about system with traction Engine.	16 to 18	40,000	14 0 0 plus ?	This is the next best system, but in actual work is likely to give frequent petty troubles and delays, due to the many parts of the tackle, the greater wear and tear on the ropes, and the numerous pulleys over which they run. Only recommended where sufficient capital cannot be found for system No. II. The troubles and delays mentioned above might easily lessen the outturn and thereby increase the cost per acre ploughed by 10 per cent. to 20 per cent.
IV	Round-about tackle with portable Engine and separate windlass. <u>Large plant</u>	"	60,000	20 14 0 plus ?	The estimate of cost of ploughing does not include the cost of moving the tackle and engine by means of bullocks. This cannot be estimated, but would be a very heavy item even if possible, the engine alone weighing 8 tons and the complete plant about 15 tons. This system is quite impracticable with large and efficient tackle.
IVa	Round-about tackle with portable Engine and separate windlass. <u>Small plant.</u>	"	80,000	28 4 0 plus ?	Here again the cost of moving the tackle by bullocks is omitted. With this small tackle the system is just possible, but would probably be found unworkable owing to difficulty of shifting and setting tackle, and finding cattle for this purpose whenever needed. The engine alone weighs 4 tons and the complete tackle about 10 tons.

System No.	Name of system.	Depth of ploughing.	Proportionate Capital cost for plant to plough 1,000 acres per season.	Cost per acre ploughed.	Remarks.
		Inches.	Rs.	Rs. a. p.	
V	Bullock-gear- ed windlass system.	16 to 18	85,000	39 0 0	Simple and certain, but too expensive and slow. It would require 110 pairs of bullocks to plough 1,000 acres per season. The estimate of capital cost does not include the price of these cattle, but is for machinery only.
I	Direct Trac- tion system.	8 to 9	20,400	8 5 0	Only suitable on quite dry and almost level land.
II	Double En- gine system	„	15,600	5 13 0	Suitable on any land if fairly dry on the headlands, and free from big tree roots or rocks. Can plough almost equally well on level or hilly land.

SECTION III.—ESTIMATES AND COMPARISONS.

SYSTEM NO. I.—DIRECT TRACTION SYSTEM.

(a) Conditions under which it is suitable.

1. Where only shallow cultivation is needed not exceeding 8 inches deep, and the shallower the better.
2. Where large open tracts of level or only slightly sloping land are to be ploughed.
3. Where the soil is light and dry.
4. Where shallow work is needed on land full of big roots or rocks, and here only if the land is sufficiently clear on the surface to enable the engine to get along.
5. Where no secondary operations are needed after ploughing.

(b) Advantages as compared with other systems.

	As compared with system No.
1. A unit plant of efficient size can be purchased for a comparatively small sum. Rs. 21,300. See Estimate 1d.	II & III
2. Some slight gain when ploughing very long furrows, (greater than the length of cable in cable drawn implements) owing to the engine not having to stop as frequently for turning.	II, III, IV, V
3. The engine is working the whole time has no idle period.	II
4. The engine driver is quite near his plough and can see when it meets a dangerous obstruction and is able to stop the engine in time, or the wheels of the engine would slip.	II, III, IV, V
5. Only one engine driver and fireman are required per shift and they are at work the whole time.	II
6. The engine is ready to commence work as soon as it reaches the field. No fixtures to be set in position.	III, IV, V
7. No cables to wear and break.	II, III, IV, V

(c) *Disadvantages as compared with other systems.*

	As compared with system No.
1. Engine absorbs from 50 per cent. to 60 per cent. of its power in moving its own weight over the land on the level.	II, III, IV, V
2. Cannot work on anything more than a very slight gradient, as on a hill all its power is required to propel itself and the pull of the plough causes the wheels to slip on the land.	II, III, IV and V
3. Cannot work on land that is the least wet, as the wheels then slip and cannot get sufficient grip to draw the plough.	II, III, IV and V
4. The weight of the heavy engine travelling over the land compresses the soil under the wheel tracks very considerably and thereby spoils the texture of the soil. This is not so important on a light dry soil, but on a heavy soil very serious damage is done to the texture.	II, III, IV, V
5. Cannot travel over the land on which one operation has been completed, hence it is impossible to do secondary operations, such as cultivating, harrowing, rolling, or seeding with the engine.	II, III, IV, V
6. Cannot plough to a greater depth than 8 or 9 inches.	II, III, IV, V
7. Cost per acre ploughed is high. See estimates Ie and IIf, and abstract of estimates.	II
8. Capital outlay <i>per acre ploughed</i> is high ... See estimates Id and IId and abstract of estimates.	II
9. On a short field will waste considerable time in turning at the ends. It has to plough alternate furrows about 100 feet apart to allow room to turn, thereby having to travel over each part of the headland several times.	II, III IV, V

SYSTEM NO. I—(d) *Estimates of Capital Outlay.*

One Class K5 (80 I. H. P.) Compound ploughing engine complete with special drawbar attachments for hauling plough, and with spare parts ...	£	625
One 4 furrow Cuban balance plough ...	...	140
One 7—9 Tyne Patent Turning Cultivator ...	...	111
One 3 flat high frame harrow ...	...	130
One four-wheeled water cart ...	...	60
Packing ...	...	44
Freight to Dhárwár from Liverpool ...	...	90
Expert European ploughman for 6 months ...	...	220
		<hr/>
	£	1,420
		<hr/>

Say Rs. 21,300.

(e) *Estimate of Annual working Expenses and cost per Acre ploughed.*

Interest on capital Rs. 21,300 at 7 per cent. per annum ...	Rs.	1,490
Depreciation on plant Rs. 18,000 at 6 per cent. per annum reckoned all the year round ...	...	1,080
Repairs on plant Rs. 18,000 at 7½ per cent. per annum for 6 months only ...	...	675
2 Engine drivers at Rs. 60 for 6 months ...	...	720
2 Firemen " " 15 " " " ...	...	180
2 Steersmen " " 10 " " " ...	...	120
Fuel (wood) say 5 khandis per day at 3/8/0 per khandi equal to Rs. 17/8/0 for 130 days ...	...	2,280
Oil, waste, etc., at Re. 1 per day ...	...	130
Allowance for cartage of 5 khandis of wood say 3 carts at 1/8/0 per day each equal to 4/8/0 per day ...	...	585
Allowance for cartage of water Rs. 3 per day for bullock and cooly hire ...	...	390
Office and establishment charges including canvasser at Rs. 50 per month for the whole year say ...	...	1,000
		<hr/>
	Rs.	8,650
		<hr/>

With this plant ploughing by direct traction it would not be possible to plough to a depth of more than 8 inches to 9 inches in black cotton soil. At greater depths the wheels of the engine would slip and it would be unable to haul the plough. 50 per cent. to 60 per cent. of the power of the engine is needed to propel itself.

It is estimated that this engine would plough 8 acres per day of 14 hours with two shifts of men to a depth of 8 inches.

Taking 130 working days total acres ploughed : equals 8 by 130 equals 1,040, acres.

Cost per acre equals $\frac{8,650}{1,040}$ equals Rs. 8/5 per acre.

NOTE :—The double engine tackle could plough about 20 acres to 25 acres per day to this depth (8 inches to 9 inches) and the cost per acre would therefore be (taking 20 acres per day and 130 days) Rs. $\frac{15,125}{2,600}$ equal to Rs. 5/13/0 per acre. See estimate II(e).

SYSTEM NO. II.—DOUBLE ENGINE SYSTEM.

(a) Conditions under which suitable.

1. Where deep ploughing is needed.
2. Where large areas have to be dealt with each season (not less than about 1,000 acres).
3. Where secondary operations, cultivating, harrowing, seeding, etc., are required after ploughing.
4. Where land is level or sloping.
5. Where soil is either dry or heavy and moist.
6. In almost all circumstances it is simplest and cheapest.

(b) Advantages as compared with other systems.

	As compared with system No.
1. Capital outlay <i>per acre ploughed</i> is low. See abstract of estimates.	II, III, IV, V
2. Cost per acre ploughed is low. See abstract of estimates.	Ditto.
3. The whole of the power of the engine is available for hauling the plough, as the engines remain stationary on the headlands and the pull is direct on the plough.	I, III, IV
4. Can plough with almost equal ease on hilly land or level land, as only the plough itself has to travel during ploughing.	I
5. The engines when not ploughing can move themselves into position on steep gradients or on fairly wet soil.	I, IV, V
6. Can plough wet soil, as long as the engines are able to move themselves into position on the headland.	I, IV, V
7. If the engines get into a nullah or hole from which they cannot move with their driving wheels, they can haul themselves out with the cable, fastened on to a tree trunk or other convenient anchorage. They can pull themselves up a slope of 1 to 1 in this way.	I, IV, V

	As compared with system No.
8. No damage is done to the soil by pressure, as the engines do not travel over it.	
The only parts at all damaged are the two headlands which can also be ploughed after the completion of the field.	I
9. Any number of operations can be done consecutively on one piece of land as the engines do not have to travel over the broken surface.	
9A. Thus ploughing, cultivating, harrowing, and seeding can be done at once or each operation at any time desired.	I
10. The time occupied in reversing the plough is very short, and it swings down into the next furrow, and does continuous work from one side of the field to the other. No time is lost in moving backwards and forwards over the headlands.	I
11. Ploughing can be done to any depth or great power exerted for other operations by increasing the power of the engines or by reducing gear and thereby the rate of working, as the whole of the power is available for hauling. It is found in practice that the maximum pull obtainable by direct traction is about 4,000 lbs. pull on the plough, after which the wheels slip. With the winding engine a pull of 20,000 lbs. or more can be obtained. These figures are not vouched for, but are given by makers of both systems.	I
12. No time is lost in shifting the engines on headlands for next furrow, as the engine which is not pulling can move into position for the next furrow, at the same time that it is paying out cable behind the plough while the other engine is pulling.	I, III, IV, V
13. There is no limit in the tackle to the distance ahead or length of headlands over which	III

	As compared with system No.
the ploughing can continue without interruption.	
The only limit is the distance apart of the headlands ; this is generally not more than 440 yards ($\frac{1}{4}$ mile) but in some cases may be increased to 600 yards.	III
If the fields are wider than this they are done in two or more strips.	
There are no fixtures of any sort to be moved periodically, as in the round-about system.	III, IV, V
14. No power is wasted in frictional and other resistances of anchors, guides, etc., and there are no pulleys in which the cable may get jammed or from which it may slip.	III, IV
15. The only frictional wear on the cable is that caused in winding it on the drum, and the cable does not have to bend round any small pulleys.	III, IV
16. There is no jolting or vibration on the engine as there would be if it were moving across the land.	I
17. The engines are clear of the dust raised by the plough.	I
18. For the above two reasons the depreciation and wear and tear on the engines is much less.	I
19. Engines can haul all the tackle and shift to fresh fields without any delay.	I, III, IV, V
<i>(c) Disadvantages as compared with other systems.</i>	
1. The initial outlay for the smallest efficient plant is high Rs. 40,000 (but is not high per acre ploughed).	I, III, IV, V
2. Double staff is required as there are two engines.	I, III, IV

	As compared with system No.
3. One engine is doing no work for half the time, except shifting to next furrow during which time it requires a small amount of fuel and water.	I, III, IV
4. An additional man is needed as signalman and great care must be taken by the engine driver to attend to signals quickly if the plough is working among strong roots or rocks.	I

SYSTEM NO. II.—(d) *Estimate of Capital outlay.*

Two Class K (80 I. H. P.) Compound Ploughing Engines complete with Patent steel winding drums and Patent self-acting Coiling Gear and with 450 yards of Fowler's Special Steel wire rope on each winding drum.

One three furrow deep plough fitted with Fowler's Patent Anti-Balance gear for ploughing 16 inches to 18 inches deep.

One nine and eleven Tyne Turning Cultivator.

One five flat, High Frame Harrow to cover a width of about 15 feet and fitted with Patent drum lifting gear.

Two four-wheeled water-carts fitted with hand pumps and suction and delivery pipes.

The above tackle complete with all necessary fittings and outfit *delivered at Dhárwár*, and including the services of an expert European Steam Ploughman for the first six months to erect and start the tackle and to teach the local men would cost Rs. 40,500.

(e) *Estimate of Annual Working Expenses and cost per acre ploughed.*

	Rs.
Interest on capital at 7 per cent. per annum ...	2,835
Depreciation on plant (Rs. 38,000) at 6 per cent. per annum reckoned all the year ...	2,280
Repairs on plant (Rs. 38,000) at $7\frac{1}{2}$ per cent. per annum for six months only ...	1,435
Four Engine drivers at Rs. 60 for six months ...	1,440
Four firemen at Rs. 15 " " ...	360
Two steersmen at Rs. 10 " " ...	120
Fuel (wood), say, 8 khandis per day at Rs. 3-8-0 per khandi, equal to Rs. 28 for 130 days...	3,640
Oil, waste, etc., at Re. 1 per day per engine ...	260
Allowance for cartage of 8 khandis of wood, say, 5 carts at Rs. 1-8-0 per day each, equal to Rs. 7-8-0 per day ...	975
Allowance for cartage of water at Rs. 6 per day for bullock and cooly hire ...	780
Office and establishment charges including canvas-ser at Rs. 50 per month for the whole year round...	1,000
	15,125

It is estimated that this tackle will plough in black cotton soil to a depth of 16 inches to 18 inches at the rate of 8 acres per day of 14 hours with two shifts of men.

Taking 130 working days equal to 1,040 acres ploughed: cost per acre equals $\frac{15,125}{1,040}$ equals Rs. 14-8-0 per acre.

Or to a depth of 8 inches to 9 inches would plough 20 to 25 acres per day. Say 20 acres.

Cost per acre equals $\frac{15,125}{2,000}$ equals Rs. 5-13-0 per acre. See Estimate Ie.

SYSTEM NO. III.—ROUND-ABOUT SYSTEM WITH TRACTION ENGINE FITTED WITH WINDING DRUMS.

(a) *Conditions under which favourable.*

1. Where deep ploughing is needed.
2. Where fairly large areas have to be dealt with each season (up to about 700 acres).
3. Where secondary operations, cultivating, harrowing, seeding, etc., are required after ploughing.
4. Where soil is either dry or heavy and moist.
5. Where capital available is too limited to allow of purchase of System No. II.

(b) *Advantages as compared with other systems.*

						As compared with system No.	
1.	Same as advantage No. 1	for system I	...			II	
2.	"	" 3 "	" " I	...		II	
3.	"	" 5 "	" " I	...		II	
4.	"	" 1 "	" " II	...		IV, V	
5.	"	" 2 "	" " II	...		I, IV, V	
6.	"	" 3 "	" " II	...		I	
Except the power wasted in friction in pulleys, anchors, etc.							
7.	Same as advantage No. 4	for system II.	...			I	
8.	"	" 5 "	" " II	...		I, IV, V	
9.	"	" 6 "	" " II	...		I, IV, V	
10.	"	" 7 "	" " II	...		I, IV, V	
11.	"	" 8 "	" " II	...		I	
12.	"	" 9 "	" " II	...		I	
13.	"	" 10 "	" " II	...		I	
14.	"	" 11 "	" " II	...		I	
15.	"	" 16 "	" " II	...		I	
16.	"	" 17 "	" " II	...		I	
17.	"	" 18 "	" " II	...		I	
18.	The movable anchors, fixed anchors, snatch blocks and rope porters can be hauled into position by the engine and do not necessitate the use of cattle					...	IV, V

(c) *Disadvantages as compared with other systems.*

	As compared with system No.
1. Same as disadvantage 8 of system No. I (only slight)	II
2. Same as disadvantage 4 of system No. II ...	I
3. After reaching the land before work can be commenced the movable anchors, fixed anchors, snatch blocks, and rope porters have to be hauled to their position in the field and firmly fixed. The perimeter of the field will be large, as much as one mile, and this work will take some time, and may be difficult. If the engine does the hauling, steam must be maintained all the time, or the tackle may be shifted by cattle, which would also mean additional expense and delay	I, II
4. The same work must be done before removing the tackle on the completion of the field ...	I, II
5. As there are a number of separate parts to be moved from field to field the actual hauling even if done by the engine would take longer and be more troublesome than if only the plough had to be moved	I, II
6. Many parts and pulleys not under the immediate inspection of the engine drivers, needing to be oiled and cleaned and liable to get out of order	I, II
The delays involved in visiting these.	
7. Great length of cable running round small pulleys and needing supports at all irregularities in the ground	I, II
8. Increased wear on cable due to above reasons, and more frequent renewals needed ...	II
9. Smaller area that can be ploughed in a season with a given sized plant, due to shifting fixtures... ..	I, II

	As compared with system No.
10. Additional men and bullocks required for shifting rope porters as work proceeds, and delays therefrom	I, II
11. Time is lost at the end of each furrow while the engine or anchor moves into position for the next furrow	II
12. In a large area not more than 30 to 40 acres can be done at one setting of the plant, after which the tackle has to be shifted and reset...	I, II

SYSTEM NO. III. — (d) *Estimate of Capital Outlay.*

	£
One Class T. I. (80 I. H. P.) Compound ploughing engine fitted with double winding drum for hauling in both directions	900
One self-moving anchor	110
Rope porters, claw anchors, and snatch blocks ...	70
One 3 furrow plough	126
One 7—9 tyne turning cultivator	111
One five flat high frame harrow	150
One four-wheeled water-cart	60
Packing	73
Freight from Liverpool to Dhárwár	100
Expert European ploughman for six months ...	220
	£ ... 1,920
	= Rs. .. 28,800

(e) *Estimate of Annual Working Expenses and Cost per acre ploughed.*

	Rs.
Interest on capital Rs. 29,000 at 7 per cent. per annum	2,030
Depreciation on plant Rs. 25,500 at 6 per cent. per annum reckoned all the year round	1,530
Repairs on plant Rs. 25,500 at $7\frac{1}{2}$ per cent. per annum for six months only	956
Two engine drivers at Rs. 60 for six months ...	720
Two firemen at Rs. 15 for six months ...	180
Two steersmen at Rs. 10 for six months ...	120
Fuel (wood), say, 5 khandis per day at Rs. 3-8-0 per khandi, equal to Rs. 17-8-0, per day for 130 days...	2,280
Oil, waste, etc., for engine and tackles at Rs. 1-8-0 per day	195
Allowance for cartage of 5 khandis of wood, say, 3 carts at Rs. 1-8-0 per day each, equal to Rs. 4-8-0 per day	585
	Carried forward ... 8,596

	Rs.
Brought forward ...	8,596
Allowance for cartage of water at Rs. 3 per day for bullock and cooly hire	390
Office and establishment charges including canvasser on Rs. 50 per month for the whole year, say ...	1,000
	9,986

It is estimated that this plant would plough 6 acres per day to a depth of 16 inches to 18 inches working 14 hours with two shifts of men. It would only be actually ploughing for 120 days as 10 extra days must be allowed for shifting tackle and resetting it.

Area ploughed equals 6 by 120, equals 720 acres. Cost per acre equals $\frac{9986}{720}$, equals Rs. 14 per acre.

SYSTEM NO. IV.—ROUND-ABOUT SYSTEM WITH PORTABLE ENGINE AND SEPARATE WINDLASS.

(a) *Conditions under which suitable.*

1. Only where a portable engine is already in use for other work and is required to plough deeply on a small area within narrow limits and where plenty of well trained haulage cattle are available for shifting the plant in the fields.

A very inefficient and laborious system.

(b) *Advantages as compared with other systems.*

						As compared with system No.
1.	A unit plant can be purchased for a comparatively small sum Rs. 12,000 ...	...	...	...	...	I, II, III
(See estimate IVc.)						
2.	Same as advantage 3 of system No. I ...					II
3.	" " 5 " " I ...					II
4.	" " 4 " " II ...					I
5.	" " 8 " " II ...					I
6.	" " 9 " " II ...					I
7.	" " 10 " " II ...					I
8.	" " 11 " " II ...					I
9.	" " 16 " " II ...					I
10.	" " 17 " " II ..					I
11.	" " 18 " " II ...					I
12.	" " 6 " " III ...					I

These advantages do not mean much when taken in conjunction with the disadvantages. Nos. 4 to 12 are merely the general advantages which every cable drawn plough has over the direct traction plough.

(c) *Disadvantages as compared with other systems.*

						As compared with system No.
1.	Same as disadvantage No. 7 of system No. I...					I, II, III
2.	" " " 8 " " I...					I, II, III
3.	" " " 4 " " II...					I
4.	" " " 3 " " III...					I, II

						As compared with system No.
5.	Same as disadvantage	No. 4	of system	No. III...		I, II
6.	"	"	"	5 " " III...		I, II
7.	"	"	"	6 " " III...		I, II
8.	"	"	"	7 " " III...		I, II
9.	"	"	"	8 " " III...		I, II
10.	"	"	"	9 " " III...		I, II
11.	"	"	"	10 " " III...		I, II
12.	"	"	"	11 " " III...		I, II
13.	"	"	"	12 " " III...		I, II

14. The engine, the heavy windlass, two movable anchors, two fixed anchors, the rope porters, snatch blocks, and the plough all have to be shifted by cattle to the field where work is to be done.

This would involve the use of a great number of cattle, would take a great deal of time and be extremely difficult even if possible ...

I, II, III, V

The engine would weigh about 4 tons (estimate No. IVc) and this alone would need probably 20 pairs of untrained bullocks to pull it on the fields.

(I have seen 20 pairs unable to move $2\frac{1}{2}$ tons on a good road lorry on ordinary dry black cotton soil.)

The windlass would weigh about 2 tons, the movable anchors about one ton each and the rest of the tackle probably another two tons.
Total 10 tons.

Even supposing it were possible to shift these at all on soft land, the difficulty of finding sufficient cattle at short notice when needed would be great and the expense would certainly ruin all prospects of the plant competing successfully with any other system, or even probably with hand digging.

	As compared with system No.
The system could only be agreed to where a portable engine was already in use for other work and where the owner was compelled to do deep ploughing on a small area, and had his own cattle for shifting the tackle ...	I,II,III,V
Even under these conditions a bullock geared plough would probably prove as cheap in the long run and would have none of the heavy risks of this system.	
15. It would certainly be impossible to move this tackle on wet ground and if caught in unexpected rain it might remain immovable for weeks or months ...	I,II,III,V

SYSTEM NO. IV.—(d) *Estimate of Capital outlay for large plant.*

	£
One 80 I. H. P. Portable Compound Steam Engine .	450
One Portable Windlass	200
Two Automatic Movable anchors	220
Claw anchors, rope porters, snatch blocks, etc. ...	100
One three furrow plough	126
One 7-9 tyne turning cultivator	111
One five flat high frame harrow	150
One four-wheeled water cart	60
Packing	80
Freight from Liverpool to Dhárwár	110
Expert European ploughman for 6 months ...	220
	<hr/>
	£ 1,827
	<hr/>
	=Rs. 27,450
	<hr/>

(e) *Estimate of Annual Working Expenses and Cost per acre ploughed, for large plant.*

	Rs.
Interest on capital Rs. 27,500 at 7 per cent. per annum	1,925
Depreciation on plant Rs. 24,000 at 6 per cent. per annum reckoned all the year round	1,440
Repairs on plant Rs. 24,000 at $7\frac{1}{2}$ per cent. per annum for 6 months only	900
Two engine drivers at Rs. 60 for 6 months ...	720
Two firemen at Rs. 15 for 6 months ...	180
Two steersmen at Rs. 10 for 6 months ...	120
Fuel (wood) say 5 khandis per day at Rs. 3-8 per khandi equal to 17-8 per day for 110 days ...	1,925
Oil, waste, etc., for engine and tackles at 1-8 per day.	165
	<hr/>
Carried forward ...	7,375

	Rs.
Brought forward ...	7,375
Allowance for cartage of 5 khandis of wood say 3 carts at 1-8 per day each equal to 4-8 per day ...	495
Allowance for cartage of water at Rs. 3 per day for bullock and cooly hire	330
Office and establishment charges, including canvasser on Rs. 50 per month all the year round say ...	1,000
	Rs. 9,200

In the above estimate no allowance is made for the very heavy item of shifting engine, windlass and tackle from place to place by bullocks.

This is indeterminate and might be a very large sum if possible at all.

The above plant is quite impracticable for India and is only shown for comparison and to answer any possible suggestions which may be and have been made, for the use of such tackle.

It is estimated that the above tackle would plough about 4 acres per day to a depth of 16 inches to 18 inches in black cotton soil working 14 hours per day with 2 shifts of men.

Assuming 110 days ploughing, total acreage ploughed equals 110 by 4, equals 440 acres. Cost per acre equals 9,200/440 equals Rs. 20-14-0 per acre.

Neglecting cost of moving plant.

The weight of the engine in the above estimate is about 8 tons and it would be impossible to move this by cattle on soft land.

The only way in which this system is practicable is to use a small engine and tackle working much more slowly.

This small plant would be still less economical than the large one estimated above, as will be seen from estimates No. IVf and IVg below.

The system cannot be recommended at all.

SYSTEM NO. IV.—(f) *Estimate of Capital outlay for small plant.*

One 6 N. H. P. (18 I. H. P.) Portable Steam Engine.	£	150
One portable windlass with cable, two self-moving anchors, one 5 tyne cultivator, Double snatch block, rope porters, and anchors	...	350
One three furrow balance plough	...	90
One set pulleys and driving chain	...	22
One two-wheeled water cart	...	28
Packing	...	70
Freight from Liverpool to Dhárwár	...	100
	£	<u>810</u>

Equal to Rs. 12,150.

This does not include an expert ploughman for the first six months, and the plant is of the cheapest possible construction.

(g) *Estimate of Annual Working Expenses and Cost per acre ploughed for small plant.*

Interest on capital Rs. 12,000 at 7 per cent. per annum	Rs.	840
Depreciation on plant Rs. 12,000 at 6 per cent. per annum reckoned all the year round	...	720
Repairs on plant Rs. 12,000 at $7\frac{1}{2}$ per cent. per annum for 6 months only	...	450
Two drivers at Rs. 45 per month for 6 months	...	540
Two firemen at Rs. 15 " " "	...	180
Two steersmen at Rs. 10 " " "	...	120
Oil, waste, etc., at Re. 1 per day for 110 days	...	110
Fuel (wood) at Rs. 3-8 per khandi say $1\frac{1}{2}$ khandis per day equal to Rs. 5-4-0 per day 110 days	...	577
Cartage of fuel $1\frac{1}{2}$ khandis say 1 cart at Rs. 1-8 per day	...	165
Cartage of water, bullock and coolies hire at Rs. 1-8 per day	...	165
	Rs.	<u>3,867</u>

This includes nothing for establishment or for shifting the tackle and engine by bullocks.

The engine would weigh about 4 tons and would be very difficult to shift on soft land.

It is estimated that this plant could plough 1 to $1\frac{1}{2}$ acres per day, 16 inches to 18 inches in 14 hours with two shifts of men.

Area ploughed equals $110 \times 1\frac{1}{4}$, equals 137 acres.

Cost per acre equals $3,867/137$, equals 28-4 per acre.

Omitting cost of establishment and shifting tackle by bullocks.

The latter item might easily cost Rs. 5 to Rs. 10 per acre depending on the size of the fields.

SYSTEM NO. V.—BULLOCK GEARED WINDLASS SYSTEM.

(a) Conditions under which suitable.

1. Only where a very small area is required to be ploughed deeply and where plenty of cattle are available.

The system is slow and expensive but will do good work on very small areas.

(b) Advantages as compared with other systems.

	As compared with System No.
1. A unit plant can be purchased for a small sum Rs. 3,200 	I, II, III, IV
2. Same as advantage No. 4 of System II ...	I
3. " " " 9 " II ...	I
4. " " " 10 " II ...	I
5. " " " 13 " II ...	III, IV
6. " " " 14 " II ...	III, IV
7. " " " 15 " II ...	III, IV
8. " " " 16 " II ...	I
9. " " " 17 " II ...	I
10. The gearings are clear of the dust raised by plough and are stationary on the headlands, so that there is no vibration and the wear and tear is reduced to a minimum 	I
11. The cattle only have to walk round on flat un- ploughed land and do not therefore injure themselves as they are likely to do in walking in the furrows 	I
They can thus utilize their full strength for pulling.	
12. The gearings and windlasses are not very heavy (only made for slow work) and the cattle can shift them when necessary without difficulty...	IV
13. No skilled attention is necessary only one trained man being needed to steer the plough.	I, II, III, IV

(c) *Disadvantages as compared with other systems.*

	As compared with System No.
1. Same as disadvantage No. 7 of System I ...	I, II, III, IV
2. " " " 8 " I ...	I, II, III, IV
3. The area done per season is very small (less than 40 acres), and the proportionate capital outlay very high so that for work on a big scale the system is unsuitable ...	I, II, III
4. One set of gearing, bullocks, and men is always idle, that is to say, both sets each work for half the day only ...	I, III, IV

SYSTEM NO. V.—(d) *Estimate of Capital Outlay.*

	Rs.
Two Bajac gearings and windlasses with all accessories.	1,800
Two Jack screws 	60
One single furrow balance plough 	572
Painting, packing, etc. 	228
Freight to Bombay from France 	316
Freight to Dhárwár 	220
	Rs. 3,196

Actual cost of plant purchased and now at work in Dhárwár District.

A Norwegian harrow costing Rs. 450 and one 5-7 tyne turning cultivator costing Rs. 480 have been purchased but are not included in above estimate as they have not yet been used.

(e) *Estimate of Annual Working Expenses and Cost per acre ploughed.*

	Rs.
Interest on capital Rs. 3,200 at 7 per cent. per annum 	224
Depreciation on plant Rs. 3,200 at 6 per cent. per annum reckoned all the year round 	192
Repairs to plant Rs. 3,200 at 6 per cent. per annum for 6 months only 	96
One steersman at Rs. 15 per month for 6 months ...	90
Oil, waste, etc., at annas 5 per day for 150 days ...	50
Transport and other miscellaneous charges 	50
Four pairs of bullocks with driver at Rs. 1-4 per pair per day 150 days 	750
	Rs. 1,452

It is found that this tackle will plough one-quarter of an acre per day in black cotton soil to a depth of 16 inches to 18 inches and can be worked for 150 days per annum.

Area ploughed equals 150 by $\frac{1}{4}$, equals $37\frac{1}{4}$ acres.

Cost per acre ploughed equals $1,452/37\frac{1}{4}$ equals Rs. 39 per acre.

LIST OF AGRICULTURAL BULLETINS PUBLISHED BY THE DEPARTMENT OF AGRICULTURE FROM 1908 TO 1912.

No.	Year.	Subject.	Price.	
			Rs.	p.
80	1908	Field, Garden and Orchard Crops of the Bombay Presidency, by G. A. Gamble, Economic Botanist, Bombay	0	12 0
81	1908	Establishment and Management of the Dairy Farm, by G. K. Kelkar, Assistant Professor of Agriculture	0	0 0
82	1908	Locusts in India, by H. M. Lefroy, Imperial Entomologist, Pusa	0	8 0
83	1909	Cultivation of Broach Cotton in Dhárwár, by M. L. Kulkarni, Divisional Inspector of Agriculture, S. D.	0	4 0
84	1909	Night-soil—A Valuable Manure, by G. K. Kelkar, Assistant Professor of Agriculture, Agricultural College, Poona	0	4 0
86	1909	Kwár in Sind, by G. S. Henderson, Deputy Director of Agriculture, Sind	0	4 0
86	1910	First Experiments in the Treatment of Grape-vine Mildew in the Bombay Presidency, by W. Burns, Economic Botanist	0	14 0
87	1910	An Examination of the Seed-supply of the Broach District, by G. D. Mehta	0	4 0
88	1910	Experiments with the Water-Finder, by H. K. Mehta, Assistant Professor of Physics, etc., Poona Agricultural College	0	5 0
89	1910	The Salt Land of the Nira Valley, by Harold H. Mann, Principal, Agricultural College, Poona, and V. A. Tambane, Laboratory Assistant, Agricultural College, Poona	0	5 0
40	1911	Cultivation of Guavas near Poona, Dhárwár and Limbgaon, by L. B. Kulkarni, L.Ag., Agricultural Department, Bombay	0	12 0
41	1911	Groundnuts in the Bombay Deccan, by G. K. Kelkar, Assistant Professor of Agriculture, Poona	0	4 0
42	1911	Note on Long-stapled Cotton in Sind, by G. S. Henderson, N.D.A., N.D.D., Deputy Director of Agriculture, Sind	0	8 0
48	1911	An Examination of the Seed-supply of the Broach District, Part II, by G. D. Mehta, L.Ag. (Bombay), B.A. (Cantab.), N.D.A., N.D.D.	0	5 0
44	1911	Preliminary Study of the Red Rot of Sugarcane in the Bombay Presidency, by G. S. Kulkarni, L.Ag., Assistant Mycologist	0	8 0
45	1911	Second Year's Experiments in the Treatment of Grape-vine Mildew in the Bombay Presidency, by William Burns, B.Sc. (Edin.), Economic Botanist to the Government of Bombay	0	14 0
46	1911	Seed Selection Series, I, Broach Cotton, by T. Forster Main, B.Sc., Deputy Director of Agriculture, Bombay Presidency, Poona	0	8 0
47	1911	San Hemp (<i>Crotalaria Juncea</i>), Tág (Maráthi), by P. C. Patil, L.Ag., Divisional Inspector of Agriculture, C. D.	0	4 0
48	1911	Poona Furnace (in the Sátára District), by P. C. Patil, L.Ag., Divisional Inspector of Agriculture, C. D.	0	7 0
49	1911	An Examination of the Seed-supply of the Ahmednagar District, Part I, by G. D. Mehta, L.Ag. (Bombay), B.A. (Camb.)	0	5 0
50	1912	An Examination of the Seed-supply of the Ahmednagar District, Part II, by G. D. Mehta, L.Ag. (Bombay), B.A. (Camb.)	0	8 0
51	1912	Third Year's Experiments in the Treatment of Grape-vine Mildew in the Bombay Presidency, by W. Burns, B.Sc. (Edin.), Economic Botanist to the Government of Bombay, and G. B. Patwardhan, B.Sc. (Bombay), Assistant Economic Botanist	0	9 0
52	1912	Muscovado Sugar Machinery and its scope for <i>Gul</i> manufacture in India, by G. N. Sahasrabudde, L.Ag.	0	8 0
53	1912	A Method of improving the Quality of Cotton Seed, by G. D. Mehta, B.A., L.Ag., N.D.A., N.D.D., and V. G. Gokhale, L.Ag.	0	7 0
54	1912	A Note on Steam Ploughing, by A. A. Musto, P. W. D., Agricultural Engineer, Bombay Presidency	0	10 0