SILSOE RESEARCH INSTITUTE

Report on a visit to

CIFEMA

CENTRO DE INVESTIGACION FORMACION Y EXTENSION EN MECANIZACION AGRICOLA

Cochabamba, Bolivia, 12-23 January 1998

Undertaken on behalf of the
International Development Group, Silsoe Research Institute
by Frank Inns
Consultant on draught animals and equipment

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ENGINEERING *for* Life

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SUMMARY

The visit to CIFEMA extended over two weeks in January 1998. Its primary purpose was to introduce the concept of a single-donkey ploughing system using a high-lift harness (*i.e.* one with a steep angle of pull — about 30° in contrast to the customary angle of 20° or less) in conjunction with a lightweight plough. This system offers reduced draught and greater efficiency compared with more 'conventional' systems.

A high-lift harness and two lightweight ploughs of slightly differing constructions were taken to Bolivia for demonstration and evaluation for potential manufacture by CIFEMA. They performed convincingly, generating considerable interest in single animal working. Enthusiasm was such that on the first working day a horse was fitted with a high-lift harness and put to work with the donkey plough, confirming that the high-lift concept is equally applicable to horse use. The high-lift system complements CIFEMA's current range of equipment aimed at use by a pair of oxen.

Following from the field demonstrations and evaluation the CIFEMA workshop built its own version of the single-donkey plough, plus an alternative ridging body for donkey use. A high-lift harness for the donkey was made locally. A single-horse plough was made using a larger share/mouldboard fitted to the donkey plough body. Preliminary trials indicated excellent performance from the donkey equipment and that a separate range of equipment for horses is desirable.

For the immediate future the work programme should concentrate on on-farm testing of the donkey plough and ridger with a view to developing it for production and sale, plus the technical development of a range of slightly larger implements for horse use. The development of other implements such as an ard-plough, single- and multi-tined cultivators can proceed alongside these activities subject to available resources. Attention should be given to the existing two-ox implements with a view to improving their performance and farmer appeal — development or replacement of the *arado reversible* is considered to be particularly desirable.

The progress of these activities should be reviewed towards the end of this year. Any remedial action should be defined and new lines for development defined and initiated. Attention will no doubt be given to student activities, such as thesis work, which can be integrated into the programme — properly managed, this can be a source of useful information and inputs.

CIFEMA has demonstrated great enthusiasm and ability for building up its expertise and relevance to animal-powered mechanisation in Bolivia. There is no doubt that it intends to maintain the impetus.

REPORT ON A VISIT TO CIFEMA

1 TERMS OF REFERENCE

see Appendix 1

2 EQUIPMENT BROUGHT FROM THE U.K.

2 x "high-lift" (HL) harnesses for donkeys, breastband type with a range of adjustments to fit various sizes of donkey and for experimental purposes.

2 x lightweight (LW) ploughs, each about 4.5 inches cut for use by a single donkey using HL harness *viz*:

- "blue plough". Original experimental plough manufactured by Project Equipment Ltd, Oswestry (now no longer trading). Weight 9.5 kg.
- "green plough". Plough manufactured by Chapel Studio, Penzance. Revised design developed for ease of manufacture in small artisanal workshops and incorporating modifications to improve performance based on field trials with the blue plough. Weight 8 kg.

Novatech dynamometer, 2.5 kN capacity (brought by B.G. Sims).

3 WORK DIARY

SATURDAY, 10.1.98

Arrive Cochabamba

MONDAY, 12.1.98

Activities

- Meet Ing. Jaime Mendoza, Director of CIFEMA, and Ing. Agr. Leonardo Zambrana Vidal, Coordinator of the Animal Traction Project, and staff.
- Review of CIFEMA's production facilities.
- Review of CIFEMA's current product range.
- Give a field demonstration of single-donkey ploughing, using HL harness and ploughs brought from U.K.
- Visit local farmers to locate a horse for additional trials.
- Field trials of a lash-up HL harness for the horse, used in conjunction with a donkey plough.
- Discussion with Leonardo Zambrana and staff of potential for HL harness systems and equipment.

Fig 1 Donkey and green plough, turning

Fig. 2: Horse and blue plough, in work

Outputs

- Familiarisation with CIFEMA's products and facilities.
- Successful field demonstrations generating much interest and confirming the Project's (and CIFEMA's) interest in comprehensive investigation of the potential for the HL harness and compatible cultivation equipment.
- Statement of CIFEMA's interest in:
  - multiple use implements with interchangeable units for ploughing, ridging, earthing up and after-cultivations;
  - introduction of working systems using horses and donkeys in addition to present use of two-ox teams;
  - lightweight (LW) implements with replaceable wearing parts, simple construction and low cost;
  - improved/alternative implements for ox teams; and
  - user-friendly equipment which is easy to adjust and use and needs only low physical effort to operate.

TUESDAY 13.1.98

Activities

- Presentation and discussion (translated by Brian Sims) of the HL harness and LW plough combination with 15 technical staff. Outline of underlying principle and operational adjustments.
- Demonstrating the use of the dynamometer to investigate the effect on plough draught of varying the angle of pull.
- Participatory field work with staff using the plough and measuring draught and angle of pull — mainly using a donkey, briefly using a horse.

Fig.3: Taking measurements to calculate angle of pull

Fig. 4: Using the dynamometer to measure pull

Outputs

- Staff gained experience in the principles and practice of adjusting and using the HL harness and LW plough, and in using the dynamometer.
- Although field conditions were rough and users were not experienced it was possible to distinguish the effects on draught arising from variations of the angle of pull applied to the plough (trends rather than accurate results), *viz* :

- for the donkey:
  31° angle of pull gave an average draught of 134 N
  25° angle of pull gave an average draught of 149 N
  13° angle of pull gave an average draught of 217 N
- for the horse:
  23° angle of pull gave an average draught of 235 N

Draught values are relatively low, probably due to low bulk density of the soil (dry and loose).

Fig. 5: Discussing the effects of a shallow angle of pull

Fig. 6: Preparing to take measurements with the horse

WEDNESDAY 14.1.98

Activities

- An intended visit to Piusilla was frustrated due to road blocked by landslides - a visit was made to Capinota (Sarcobamba) instead.
- The main farm site visited at Sarcobamba consisted of a large area of reclaimed riverine silt, free of vegetation, level, homogeneous and moist, with a medium to high bulk density.

A farmer's donkey was brought, harness was fitted and the green plough attached and set to work. From the start it worked level and at a near-uniform depth of work with no need for other than the slightest control forces, *i.e.* the plough responded positively and decisively to near-perfect soil conditions. It was tried by six or more farmers, none of whom had any difficulty in handling it to good effect, including single-handed operation and control of the donkey/plough combination. Farmers were asked for their comments on the plough (see "Outputs" below).

A farmer asked to try using the plough with a horse and one was fetched from his farmstead. Similar excellent results were achieved. The use of the dynamometer was demonstrated at this stage and, at a pull angle of 27° the average draught was found to be 377 N, with an average depth of work of 15 cm.

The farmer mentioned that he used a ridger to open a furrow for planting and was invited to fetch and demonstrate it. It was a wooden steel-tipped ard with small wings, pulled by means of a wooden frame with shafts each side attached at a high point on a belly-band on the horse (the farmer said that a breastband was usually used in addition, taking the pull from the bellyband). The ard worked well with good stability. A similar harness was available for a single donkey and the ard was provided with an ingenious adjustment to suit the smaller animal although it seemed to experience some difficulty in pulling it.

While returning, one of CIFEMA's *"arados de montaña"* was observed at work in a neighbouring field. It was found to be running out of alignment, about 15° nose-down. This had apparently caused high wear on the share.

Fig. 7: Discussing plough performance at Capinota

Fig 8: Using a horse to pull the donkey plough at Capinota

Outputs

- Farmers' comments on the green plough — they:
  - liked the shape of the share and mouldboard;
  - appreciated the ease of control;
  - would like a shorter and more upright handle — they suggested moving it forward about 10 cm to bring the operator nearer to the animals, making it easier to control them;
  - would like to see a ridger built to the same principles;
  - would like a larger version of the plough and ridger to be available for use with a horse; and
  - expressed a preference for an implement having a rigid frame as in their own adaptation of the ard.

  There is a need for:
  - trials to evaluate optimum handle position;
  - a single donkey ridger to be designed and made
  - comparative trials of the locally made rigid-frame implement against the flexible traces of the HL harness (the author has some reservations about the farmers' instant preference for the rigid frame bearing in mind their limited acquaintance with the rope-traces/swingletree design. Availability, selection and workability of high-grade timber, necessary to produce a light weight frame, would be a problem in factory production. Excessive warranty claims for breakage are also possible).

  The *arado de montaña* should be examined with a view to limiting the range of adjustment for the angle between the beam and the body to a necessary minimum, reducing the risk of excessive maladjustment. A "picture book" style instruction manual or leaflet should be developed to illustrate correct practice.

THURSDAY 15.1.98

Activities

- Visit to Piusilla (San Isidro) by alternative route to previous day's attempt.
  The visit involved crossing the Cordillera Oriental at a height of about 4200 m before descending to Piusilla (3500 m). The farming pattern throughout the journey was characterised by small steeply sloping (up to 45°, sometimes more) plots with scattered

distribution of varying intensity and length of fallow. Soils were mainly sandy loam of medium density with many stones up to 10 cm in size (larger ones mostly cleared and placed to help make a bund). Both soils and topography were in marked contrast to those of the previous day: mechanisation problems, including the use of animal traction, were correspondingly more severe.

Stops were made to examine various field trials set up by University staff and/or students, mostly agronomic but including a trial to investigate the effects of various preliminary cultivations before hand ridging and planting with potatoes — unfortunately not obviously conclusive (subject to harvesting and analysis).

It was not possible to demonstrate the HL harness and LW plough as virtually all of the able-bodied male population were away for the day attending a political meeting. The Project Coordinator made a brief presentation to a group of ladies.

Return to Cochabamba was delayed by several hours due to barricaded roads, being a demonstration by neighbouring residents against proposed extraction of local water resources.

Fig. 9: Explaining the potential of the donkey plough at Piusilla

Fig. 10: — and making a start on trying it out

Outputs

- An appreciation (far from comprehensive!) of the problems posed to draught animal mechanisation by soils and topography of hillside farms — and of the effects of localised political activities.

FRIDAY 16.1.98

Activities

- Meeting to define the work programme for the rest of the week.
- Discussion on manufacturing a single-donkey plough, selecting features from blue and green ploughs as appropriate. Identifying available materials in-store and locally and purchasing as required.
- Discussion of procedures and various techniques for manufacture.
- Giving guidance as manufacturing starts.

Outputs

- Decision to manufacture single-donkey (4.5") and single-horse (6") CIFEMA prototype ploughs with adjustable handles for on-farm trials. Decision to manufacture single-donkey and single-horse ridgers with adjustable widths of cut, with design of the bodies guided by a locally constructed donkey ridger as owned by CIFEMA.
- Commencement of manufacture of the ploughs.

SATURDAY 17.1.98

Activities

- Preparing paper to be presented at a seminar on Tuesday 20.1.98 (translation by Brian Sims).

Output

- Draft paper ready for processing on Monday 19.1.98

MONDAY 19.1.98

Activities

- Arrange production of paper for next day's seminar.
- Discuss details of the design for the CIFEMA prototype of the LW donkey plough and of a 6" horse-pulled version.
- Examine in detail the possibility of using the body from existing small ridger for attachment to the LW plough frame.
- Report writing.

Outputs

- Seminar paper finalised and 20 copies produced.
- Decision to build the LW donkey plough with r.h.s. (rectangular hollow section) beam and welded frame as on the blue plough with body as on the green plough. A single handed handle adjustable for height and fore-and-aft position to be fitted to the prototype for evaluation of farmer preferences.
- Detailed arrangements for adaptation of the ridger body worked out.
- Report part written (first week's activities and outputs).

TUESDAY 20.1.98

Activities

- A seminar entitled "Arnés de alto levante más arado liviano: un sistema de arado eficiente y de baja fuerza de tiro" was presented to 32 participants from a variety of organizations. A copy of the seminar paper is reproduced at Appendix 2.
- Following the seminar a field demonstration was held, attended by the participants, at which the green plough was demonstrated pulled by a donkey and the blue plough pulled by a horse.
- A meeting was held to discuss local manufacture of a copy of the donkey harness.
- Problems in the performance of CIFEMA's reversible plough were discussed with the Project Coordinator — in particular excessive force was needed to control it and hold it in work.

Fig. 11: Conference delegates discuss the high-lift harness and lightweight plough system

Fig. 12: — and measure its performance

Outputs

- The concept of the HL harness and LW plough, and CIFEMA's interest in their production were disseminated to an influential group and their application to working with donkey and horse were successfully demonstrated.

A detailed specification, including dimensions, was drawn up for the donkey harness — see Appendix 3.

Performance of the CIFEMA reversible plough was observed in the field. It was decided to attach a fin to the sole of the plough at the rear to resist side thrust, which alternates from one side to the other when the plough is reversed. The modified plough to be tested in the field on the following day.

WEDNESDAY 21 .98

Activities

- Helping with plough production.
- Discussion of the adaptation of the ridger body to plough frame and helping with its production.
- Modification of the reversible plough, as discussed the previous day, followed by field trials.

Outputs

- Plough and ridger production going ahead.
- Field trials of the reversible plough showed no improvement in performance — the backward rake on the leading edge of the fin rode heavily on the soil part of the way up the furrow wall (which is not vertical, but set at an angle of about 60° to 70° due to the shape of the share on this reversible plough) and may have caused some loss of penetration. It was decided to try a forward raked fin with clearance behind the point to eliminate support from the fin. It was considered also that the rounded shape of the share "point" was supporting the front of the plough and causing loss of penetration — it was decided to try to eliminate this support by fitting a more conventional sharp point to the share.

THURSDAY 22. .98

Activities

- Meet with Ing. Jaime La Torre, Dean of the Faculty of Agronomic, Livestock, Forestry and Veterinary Sciences.
- Assist with design and manufacture of a 6" mouldboard to be fitted to the single-donkey plough in place of the 4.5" mouldboard, with the intention of making it more suitable for use by a horse.
- Further modifications made to the reversible plough (see previous day's outputs) and field tests undertaken.

Fig. 13 Fitting the plough body to the CIFEMA frame

Fig. 14: Prototype production complete — Edgar Cafari and Porfirio Gamez with green plough: CIFEMA frame and 6" body, 4 ½" body (fitted), ridging body: blue plough

Outputs

- The Dean of the Faculty expressed his interested on hearing of the purpose of the visit and results so far.
- Manufacture of the plough frame was completed, with optional attachments to provide for:
  - 4.5" plough body;
  - 6" plough body;
  - ridger body with adjustable wings.
- Field tests of the reversible plough showed that the forward raked fin quickly clogged with vegetation. Tests with the modified share point showed that this gave significant improvements in penetration, control and stability in work, with consequent reduction in effort required from the operator. Further significant improvements are not likely without a major redesign exercise.

FRIDAY 23.1.98

Activities

- In-field test of equipment manufactured during the week. The donkey was used with a new locally manufactured harness adjustable by buckles rather than the knotted adjustments of the experimental harness brought from the U.K. This was tried in conjunction with the 4.5" plough and the ridger. The 6" plough and the ridger were tried with a horse.
- Review of results and discussion of future programme.
- Social meeting with project staff and students

Outputs

- The locally manufactured donkey harness was well made and easier to adjust to give a good fit, compared with the one brought from the U.K.
- The donkey worked well with the 4.5" plough and the ridger. Ridger performance could probably be improved by reducing the support experienced by the keelplate (raise the rear end of it to give it a horizontal setting) and lower end of the implement frame which extended below the keelplate. A modified mouldboard shape should be tried with 3 to 4 mm cut from the lower edges and 20 to 30 mm added at the top edge with more curvature

to the mouldboard to assist with turning of the soil.
The horse worked well with the ridger but the plough performance when fitted with the 6" body seemed somewhat deficient in terms of penetration and stability. The donkey-plough frame should be replaced by a slightly larger and heavier (11 to 12 kg) custom-built frame more suited to the 6" mouldboard.
Further details of suggested modifications to CIFEMA's implement range are given in section 5 of this report.

Fig. 15: Donkey with locally made harness and 4 ½" CIFEMA plough

Fig. 16: Horse ploughing with 6" CIFEMA plough (temporary local harness)

Fig. 17: Donkey with locally made harness and CIFEMA ridger

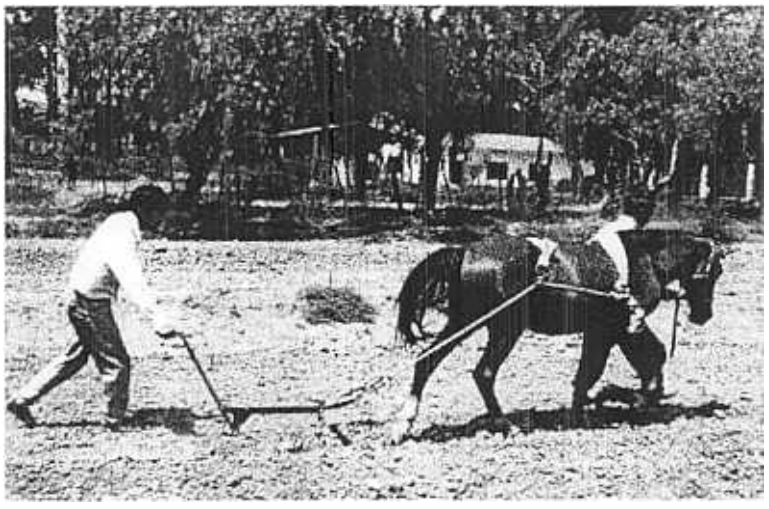


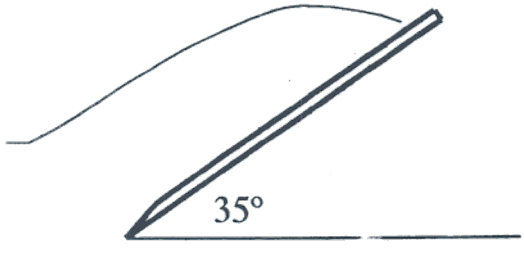
Fig. 18: Horse with CIFEMA ridger (temporary local harness)

4 COMMENTARY

CIFEMA has been successfully manufacturing and marketing a range of agricultural machinery for some 15 years. Its major efforts have been directed to production of a range of beam-pulled implements for use by a team of two oxen with a head yoke. The most popular implements for hillside work are a reversible mouldboard plough (*arado reversible*) and an ard type plough (*arado combinado*) which may be fitted with a range of attachments for tine cultivation (*carpidora*), furrow making (*surcadora*), earthing up (*aporcadora*) and lifting potatoes (*cavadora de papa*). For hillside work these implements are required to work on slopes up to 45°, sometimes more — they may also be used for lowland work in relatively level fields. Two other implements — a fixed body plough (*arado de montaña*) and a levelling harrow (*rastra de aletas*) — are not suitable for hillside work and are generally used only on flat or gently sloping land.

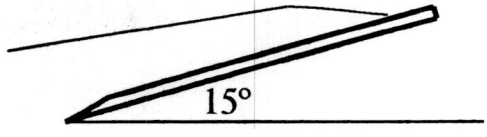
CIFEMA is currently undergoing a reorganisation to fit it for its new role as a commercially responsible manufacturing unit. A Swiss consultant will be arriving soon to advise on workshop layout to promote manufacturing productivity. On this visit there was little time available to review CIFEMA's existing range of beam-pulled implements but, as mentioned in the work diary (section 3 of the report, above), some attention was given to difficulties of penetration and control experienced with the reversible mouldboard plough. Significant improvements were made by fitting a point to the ploughshare but more fundamental changes are desirable to further improve its performance in hillside working. These are not likely to come easily and a radically new design may be needed.

The designs of other CIFEMA implements, such as the *arado combinado* and the *arado de montaña*, appear to be basically sound but would benefit from a survey to check that they are being correctly used in the field. The angle at which the beam is attached to the implement is a critical adjustment for correct running and hence maximum useful work output. If the body is set at too steep an angle it may generate its equilibrium working draught by bulldozing the soil, which is less efficient than its correct mode of operation with the implement body set at a shallow angle to give good penetration, lifting and breaking of the soil, as shown in the diagrams below.



BAD

Bulldozing: share is set at too steep an angle — more than 30º
Less useful work for the same draught



GOOD

Lifting and bursting: share is set at a shallow angle — about 15º
More useful work for the same draught

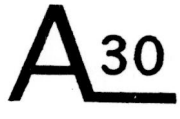
These comments arise from seeing an incorrectly set *arado de montaña* at work at Capinota. It is not known how common such maladjustments are, but it should be possible to reduce their occurrence by limiting the range of adjustment between the implement body and the beam — at present there is provision for a wide range of adjustment and consequently greater opportunity for maladjustment.

The high-lift harness and lightweight plough which are the major subjects of the terms of reference for this visit can be seen as representing a range of chain-pulled implements which are complementary to the existing beam-pulled range. The high-lift concept is particularly appropriate for use by single animals, including lighter and less powerful animals such as donkeys, but extending also to single horses, mules and oxen (singly or in pairs) if required. Donkeys and horses are already used for draught purposes using mainly traditional implements and there is little doubt, judging from the enthusiasm shown by project staff and by farmers at Capinota, that there is a potentially active market for more effective equipment and that there is a readiness to try them out.

Efforts during this visit were therefore concentrated on explaining and demonstrating in the field the advantages of the HL harness and LW implement system, and assisting in the trial production in CIFEMA's workshops of the basic frame for donkey-pulled implements with a 4.5" plough body and a ridger body as alternative bolt-on attachments. Each of these configurations weighed about 8 kg and performed very well when tested at CIFEMA's on-site field area, doing a good job with easy adjustment and control and with a draught which the donkey seemed to accept without any obvious signs of work stress. These implements are now ready for trial manufacture of a small batch for testing and evaluation on-farm, including evaluation of the donkey's ability to pull the implement for a full working day.

The applicability of the HL concept for use by horses was tested by using the donkey plough which worked well, but the donkey size plough was not loading the horse to its full pulling potential — a larger plough was needed. To investigate the potential for a slightly larger plough the 4.5" mouldboard of the original plough was replaced by a larger 6" mouldboard with no other changes to the frame or frog. This first attempt at building a horse plough performed reasonably well but did not run as sweetly as the donkey plough. There was little increase in draught and the wider body led to a slight decrease in depth of work (cross-sectional area of cut remaining approximately the same) and less directional stability. It is suggested that a little more weight is needed to give a well-proportioned cross-sectional area matching the increased draught which a horse can provide — a weight of about 11 kg to 12 kg should be suitable. Frame strength should be increased and a slight increase in frame size might also be useful to give more under-beam clearance, bearing in mind that the hake adjustment must be arranged to maintain its compatibility with a harness pull angle of 30° or so. A horse-pulled ridger should have a similar weight with body size increased accordingly.

It must be emphasised to farmers that the benefits of the HL harness and LW plough system depend on the use of a harness giving a pull angle of about 30° and implements which are designed to match. Farmers should be encouraged to use a harness to CIFEMA's specifications, with sufficient adjustments to ensure a comfortable fit on their particular animals. It will no doubt be easier to establish the use of such a harness if it is specified from the start rather than trying to force a change from a less satisfactory design at a later point in time. It would be worthwhile to identify the compatible range of implements by adopting a trademark or logo such as:



to be marked on all "Alto Levante 30°" implements.

5 FUTURE PROGRAMME

It is suggested that priority should be given to the items which are underlined.

High-lift harnesses

Donkey harness

- Design of the donkey harness (Appendix 3) and potential for local manufacture appears to be satisfactory, subject to on-farm testing and evaluation. <u>Its adoption by farmers wishing to use the HL harness and LW implement system should be actively promoted</u>.

Horse harness

- The proposed horse harness had not been made at the time of departure (24.1.98). No major problems are foreseen but, when available, it must be tested and evaluated in combination with the horse-pulled plough and ridger and be shown to perform satisfactorily before promoting it to farmers.

Harnesses for other animals

- It might be necessary to design a mule harness, of similar configuration, subject to demand.
- A high lift harness for a single ox should be feasible but would have a rather different configuration from the breastband type, which is more suitable for equines. Possibly two different types will be needed for Zebu (*bos indicus*) and taurine (*bos taurus*) cattle. However, farmers are not likely to wish to convert from their current usage of oxen in yoked pairs and therefore development of a single-ox HL harness is not recommended until such time as a positive demand is detected.

Donkey-pulled implements

Donkey plough

- Both the green donkey plough and the version built by CIFEMA work well. A batch of the CIFEMA model should be built for on-farm tests and farmer evaluation with donkeys — it should then be possible to finalise the design, *e.g.* position of the handle. It is recommended that a small batch of ploughs should be built with the beam and leg formed from 40 x 10 flat steel (as in the green plough) in order to compare manufacturing costs and on-farm performance.

Donkey ridger

- The donkey ridger worked well in preliminary field trials and a CIFEMA prototype should be built in accordance with the specification in Appendix C1 for further field trials. Subject to satisfactory performance a batch should be produced for on-farm evaluation.

Other donkey-pulled implements

- The donkey plough and donkey ridger are better suited to relatively flat land. Primary cultivation for hillside working would be better undertaken with tined implements, either an ard (similar to the basic tine of the ox-pulled *arado combinado*) for harder stony soils or a more vertical deeper working tine for lighter soils. A three-tine weeder/scarifier is another possibility. Each of these implements is a considerable design challenge, particularly to achieve stability and control in work. The three-tine cultivator is probably the easiest to deal with and the ard is probably the most difficult. There is a need to evaluate the market potential for each of these implements and identify priorities for expenditure of development efforts.

Horse-pulled implements

Horse plough

- Further development work is needed to produce a satisfactory design — see Appendix B2 and commentary in section 4 of this report — followed by field trials and on-farm evaluation.

Horse ridger

- Further development work is needed to produce a satisfactory design — see Appendix C2 and commentary in section 4 of this report — followed by field trials and on-farm evaluation.

Other horse-pulled implements

- The same remarks apply as for other donkey-pulled implements. Development priorities between donkey-pulled and horse-pulled implements in the "other implements" category. The development of horse-pulled versions of the ard, single and three-tine cultivators would probably be easier than for donkey-pulled versions. A decision on whether to give development priority to horse or donkey-pulled versions should depend on the relative availability of horses and donkeys for hillside farming systems, as determined by survey.

Seeders and planters

It is notoriously difficult to design a reliable seeder or planter which is also simple, cheap and user friendly (light, easy to adjust and manoeuvre, adaptable to a wide range of seeds and soil conditions). A major difficulty is that metering mechanisms tend to clog easily, with effects which often only become evident in the field after germination. Probably the best metering mechanism for animal drawn seeders is the inclined plate as used on the "Super Eco" seeder produced in Senegal by SISMAR. These machines work well on fine light soils with level surfaces, but are not likely to be so good in more demanding conditions, particularly sloping land. Closer to home the Brazilian company, Metalurgica Santa Antonio of Santa Barbara d'Oeste, advertises an animal-pulled precision drill. It should be possible to purchase samples for on-farm trials in Bolivia as a first step to evaluating the potential production and acceptability of animal pulled seeders.

It is the author's opinion that most small-scale farmers prefer the known reliability of seeding and planting by hand, which tasks are not usually too onerous, and that the development of animal-pulled machines is not a high priority. Many organisations have already expended considerable resources on developing seeders, with little uptake by farmers.

CIFEMA's existing range of machinery

Arado reversible

- In the time available it was not possible to make a detailed evaluation of the range of machinery currently produced by CIFEMA. One pressing problem, *i.e.* penetration of the *arado reversible* was investigated and some remedial action was defined, as mentioned in Section 4 above. However this can be regarded only as a palliative measure. The *arado reversible* is fundamentally a flat-land plough and a design which is more suited to hillside work is needed. ALGHESA of Lima, Peru, advertises a reversible mouldboard plough for mountainous conditions, weighing 16 kg. No details are to hand for a desk-top evaluation — it may be worthwhile to buy one for on-farm evaluation as guidance for a potential replacement for the *arado reversible*.

APPENDIX 1

TERMS OF REFERENCE

Professor F M Inns

Bolivia: 12-23 January 1998

1 With specified groups demonstrate the use and adjustment of a single-donkey "high-lift" harness in combination with a compatible lightweight plough, measure its performance, discuss the potential benefits of the system to various categories of farmers (and to their draught animals), identify those farmers likely to have the means and the commitment to explore and benefit from its adoption and consider the most appropriate implements to meet their farming objectives.

2. Discuss local manufacture of the necessary harness and implements and how to adapt the existing designs to suit local availability of constructional materials and facilities.

3. Participate in manufacture of harnesses and ploughs.

4. Participate in farm trials and undertake farmer assessment.

5. Discuss necessary design features of a desirable range of implements.

6. Discuss and formulate future programme of work, including potential research topics.

7. Present a seminar on the use of donkeys in single animal cultivation operations.

8. Prepare a report on completion of the work.

B G Sims
Silsoe Research Institute **27 November 1997**

APPENDIX 2

SEMINAR PAPERS

The papers in this Appendix relate to a seminar held at CIFEMA on 20 January 1998.

The seminar was prepared in English by Frank Inns and translated into Spanish by Brian Sims.

Presentation was in English, with ongoing interpretation into Spanish by Brian Sims, who also acted as interpreter for the ensuing discussion.

The presentation was followed by demonstration of the high-lift harness and lightweight plough system in a neighbouring field, including demonstration of measuring techniques for implement draught investigations.

A Invitation to attend the conference and demonstration from Ing. Agr. Leonardo Zambrana Vidal, Coordinator of the Animal Traction Project at CIFEMA, to various organisations and individuals.

B List of participants

C English version of the paper

INVITATION

CENTRO DE INVESTIGACION, FORMACION Y EXTENSION EN MECANIZACION AGRICOLA
UMSS - COSUDE
Casilla 831 — Teléfonos 25515 - 34994 — FAX (591-42) 34994 — Cochabamba - Bolivia

Cochabamba, 13 de enero de 1998

CIFEMA 002/98

Señor (es)
CARRERA DE VETERINARIA
Atn.: Dra. Elfy Vaca
Presente.-

Ref.: INVITACION A CONFERENCIA Y DEMOSTRACION DE CAMPO SOBRE TRACCION ANIMAL

De nuestra mayor consideración:

El Proyecto Mejoramiento Tracción Animal - CIFEMA tiene el agrado de invitar a profesionales de su Institución a la Conferencia y Demostración de campo sobre el uso de arneses e implementos de labranza para tracción con equinos (caballos y asnos), la misma a cargo del Dr. Frank Inns, experto en tracción animal del Silsoe Research Institute-SRI del Reino Unido.

La conferencia y la demostración de campo se efectuará el día martes 20 de enero 1998, de hrs 09:oo a 12:oo en las instalaciones de CIFEMA, Av. Petrolera Km 4, La Tamborada.

Insinuo confirmar su asistencia a los teléfonos 25515-34994.

Atentamente,

Ing. Agr. Leonardo Zambrana Vidal
COORDINADOR
PROYECTO TRACCION ANIMAL

cc. Archivo

LIST OF PARTICIPANTS

LISTA DE PARTICIPANTES
"USO DE ARNESES E IMPLEMENTOS DE LABRANZA
PARA TRACCION CON EQUINOS
20 de enero de 1998

No	NOMBRE	INSTITUCION	DIRECCION	TELEFONOS	FIRMA
1	CONSTANCIO HINOJOSA	PROYECTO LADEROS	FCAP	38146	
2	OMAR GUAYGUA AJATA	"	"	"	
3	Roger Flores	"	"	"	
4	IAN COKER	"	"	"	
5	GUY GALINDO A.	A.S.A.R.	AV. BARRIENTOS	59477	
6	[illegible]	P. Tracción Animal	CIFEMA	25515	
7	Marcelo A. Díaz	P. Tracción Animal	CIFEMA	25515	
8	Patricia Torrejón S.	CIFEMA	CIFEMA	25515	
9	Juan Carlos Céspedes C.	P. Tracción Animal	CIFEMA	25515	
10	David Alconcá	PEIRAV	FCAP	50329	
11	Oscar Delgadillo	PEIRAV	FCAP	50329	
12	Milton Copa Morató	LADERAS	FCAP	38844	
13	Victor Fernandez Rivas	ETSA	ETSA	22001	
14	Guido Zgarra H.	ASAR	Av. Barrientos	59477	
15	Jose Gomez M.	CIFEMA	Av Petrolera	75515	
16	Tomas Villarroel	Agropecuaria P.	Alquile	—	
17	Franz Gutiérrez	CIF-UMSS	CIF "La Violeta"	88579	
18	Tatiana Espinoza B.	Proyecto LADERAS	FCAP	38146	
19	Margoth Cabrera	PROSANA	Magallanes N°30	80585	
20	ADOLFO ARMENDARIA	FAO-PROSECHA	TARIJA # 1589	43114	
21	Carim Rojas Madrano	CIFEMA	Av. Petrolera Km 4½	25515	
22	Jaime Arandia C.	CIFEMA	2 de agosto	50379	
23	JUAN ALEMAN D.	FAO-FERTISUELOS	LAS BRISAS 16	43933	
24	Emilio Trujillo R.	CIAPROT	Jaime Mendoza 1646	85386	
25	JUAN GUAYGUA A.	PROSANA	MAGALLANES N° 1530	80585	
26	J. Alfonso Escobar B.	SEFO-SAM	Tigo Paya "Fundo la Violeta"	8-8646	
27	Leonardo Zambrana	CIFEMA	LA TAMBORADA	25515	
28	Ludwing Tapia	CIFEMA	La tamborada	34994	
29	EMIGDIO CESPEDES	PROYECTO LADEROS	FACULTAD AGRONOMIA	38146	
30	Julio C. Ledo G.	ETSA	ETSA. Av. Petrolera S/N	37501-22001	
31	JUAN GARCIA Castillo	SNAG	Av. Oquendo 1005	22536 21619	
32	JULIO C. ANTEZANA C.	P. TRACCIÓN ANIMAL	CIFEMA	87274	
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COPY OF THE COMPLETE ENGLISH VERSION OF THE PAPER

HIGH-LIFT HARNESS

and

LIGHTWEIGHT PLOUGH

AN EFFICIENT LOW-DRAUGHT PLOUGHING SYSTEM

by FRANK INNS

for a Seminar held at

CIFEMA

CENTRO DE INVESTIGACION FORMACION Y EXTENSION EN MECANIZACION AGRICOLA

Cochabamba, Bolivia, 20 January 1998

INTRODUCTION

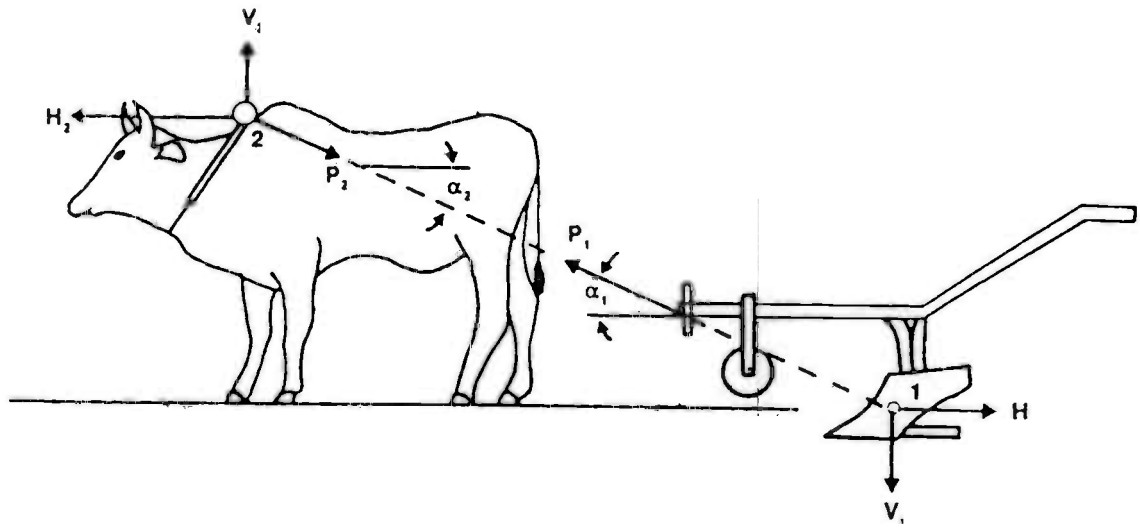
Our discussion today deals with the use of animals in combination with various implements which are used for soil cultivation operations. For effective work a suitable harness must be use to connect animal(s) and implement.

Although much research has been conducted into harnessing of animals, it has nearly always been done in isolation without considering the interaction between animal and implement and hence their fundamental suitability for the animals and implements involved. Similarly, implements have been designed in isolation and it has been left to chance whether their use is compatible with the various harnessing systems which different farmers may wish to use. The result has often been implements which the animal cannot pull comfortably throughout a full working day. The required draught force may be too high. Also, implements may be difficult, or impossible, to adjust correctly so that the operator must exert excessive forces to hold them in work.

In contrast the harnessing (called hitching) arrangements between tractors and their implements have been studied in great depth and detail so that implement and tractor are enabled to give them optimum performance. Similar studies made recently for draught animals and their implements have given rise to the concept of a "high-lift" harness used in conjunction with a lightweight implement, which has been evaluated in practice and which will now be outlined.

PRINCIPLES OF OPERATION 1

FORCES BETWEEN THE ANIMAL(S) AND A CHAIN-PULLED IMPLEMENT



FORCES ACTING ON THE IMPLEMENT

H_1 = implement draught
P_1 = pull in the chain
V_1 = effective vertical force acting on the implement
= implement weight ± soil forces ± forces from the operator
α_1 = angle of pull

FORCES ACTING ON THE ANIMALS

H_2, P_2 and V_2 are corresponding forces, of the same magnitude, exerted by the animals
Angle α_2 has the same magnitude as α_1

BASIC RELATIONSHIP BETWEEN FORCES

Analysis of forces shows that:

$$H = \frac{V}{\tan \alpha}$$

This equation shows that implement draught is reduced when:

- the effective vertical force V is reduced

and/or

- the angle of pull α is increased

And *vice versa*

PRINCIPLES OF OPERATION 2

IMPLICATIONS OF THE HIGH-LIFT HARNESS/PLOUGH SYSTEM

The high-lift system makes use of:

- a 'high-lift' harness which gives a steeper angle of pull between the draught animal(s) and the plough, compared with traditional harnesses;
  and
  a lightweight plough designed to work with the steeper angle of pull.

The combination of reduced plough weight and increased uplift on it arising from the steeper angle of pull reduces the load carried by the wheels of a wheeled plough or, in the case of a wheel-less plough, the load reduction occurs between the underside of the plough and the soil. Rolling resistance at the wheels is reduced and/or the frictional resistance underneath the plough. Plough efficiency is improved by reducing these parasitic components of draught.

Field experiments have shown that, for a particular soil type and condition, plough draught is halved approximately when the pull angle is increased from 20º to 30º (see "Principles of Operation 3"). The steeper angle of pull can be obtained quite easily, e.g. by using a hip strap (see "Harness Design").

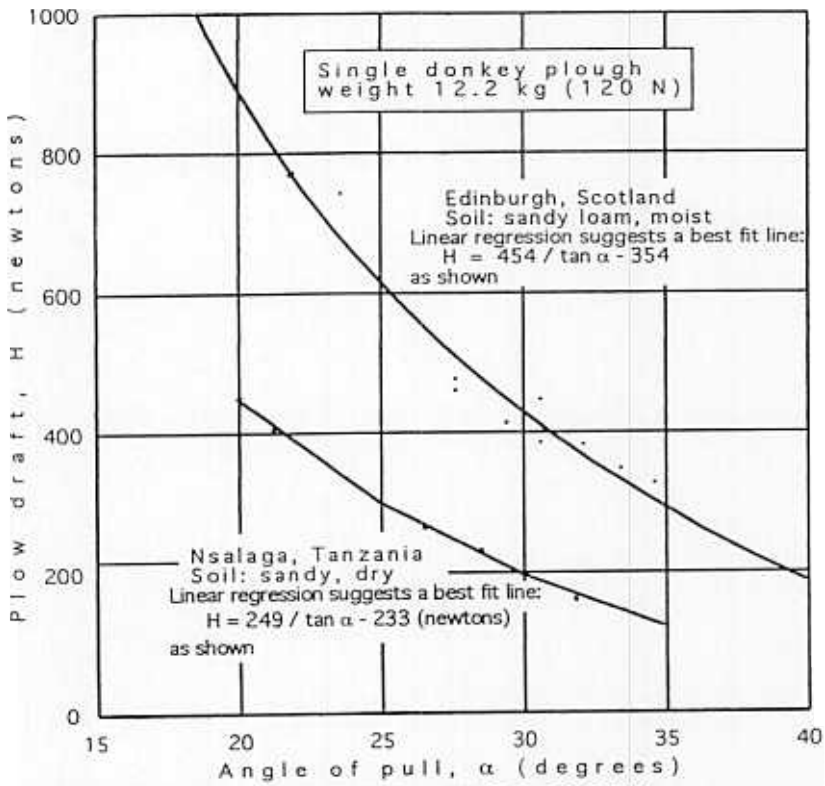
Advantages of the high-lift system include:

improved plough efficiency (greater proportion of useful work);
reduced draught load on the animals (or more useful work for the same draught level);
easier adjustment (skids or wheels are not needed); and
lighter plough (cheaper, more easily transported and handled).

The high-lift harness/plough system can be used with all commonly used draught animals including horses, mules, donkeys and oxen. It is particularly useful for single animal working and with smaller animals such as donkeys.

PRINCIPLES OF OPERATION 3

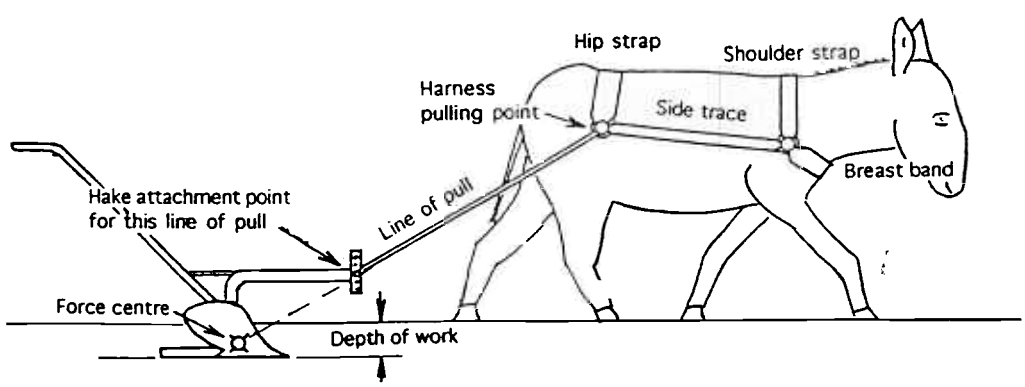
RESULTS FROM SOME FIELD EXPERIMENTS



VARIATION OF DRAUGHT WITH ANGLE OF PULL:
RESULTS FROM FIELD TRIALS IN SCOTLAND AND TANZANIA

HARNESS DESIGN

TYPICAL HIGH-LIFT HARNESS (BREAST BAND TYPE) SUITABLE FOR DONKEYS AND OTHER EQUINES



This harness gives an angle of pull of about 30º or slightly more

OPERATIONAL ADJUSTMENTS

ADJUSTMENT PROCEDURES FOR SETTING A LIGHTWEIGHT PLOUGH INTO WORK

Plough adjustment aims at getting the plough to run "sweet and level" so that:

- the body runs level with correct clearance under the share and body. This is the most efficient attitude for a mouldboard plough, giving the greatest useful soil disturbance for least draught. Get to know the correct "set" of the plough — what it looks like when the body is running at its most efficient attitude. When the plough has a straight beam it usually, but not always, runs parallel to the ground surface.
- the operator needs to apply only the slightest of forces at the handles, and solely for corrective action.

Guide the plough don't fight it!

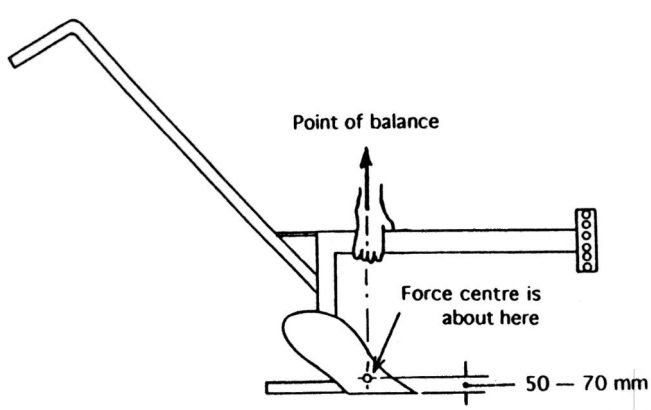
Note: A high-lift harness with lightweight plough does not need a nosewheel or skid.

Force centre ("centre of resistance")

The force centre is important to correct plough setting. Its position is closely associated with the plough's centre of gravity and may be found with reasonable accuracy as shown in Operational Adjustments 1 below (in fact the force centre is not a fixed point, but its position varies only slightly and probably less for a lightweight plough than for a heavier one).

OPERATIONAL ADJUSTMENTS 1

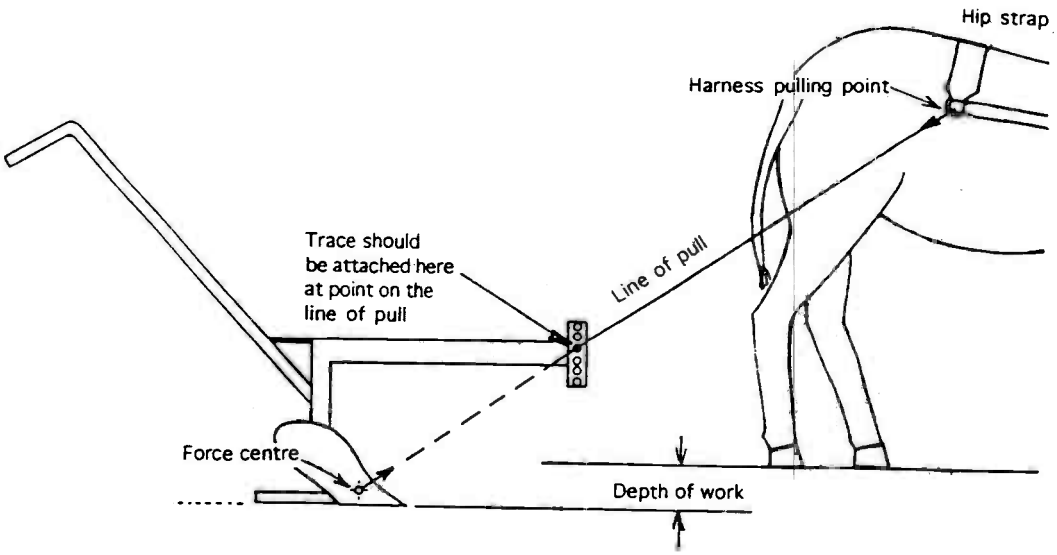
FINDING THE POSITION OF THE FORCE CENTRE, APPROXIMATELY



The approximate position of the force centre is directly below the centre of gravity (point of balance) and about 50 to 70 mm above the furrow bottom, as shown

OPERATIONAL ADJUSTMENTS 2

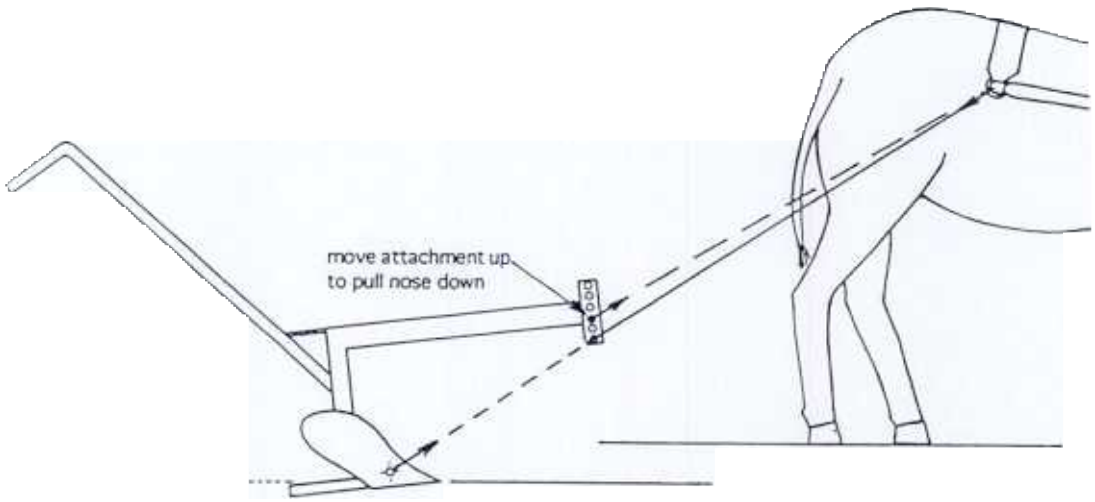
SETTING THE PLOUGH INTO WORK



1. Put the plough in its correct working position relative to the draught animal
2. Assess the required line of pull — it joins the pulling point on the harness and the force centre on the plough
3. Attach the traces to the plough hake or regulator at the position which coincides with the line of pull
4. If the plough does not run level when in work, adjust the point of attachment at the hake. The operator should not need to use force to achieve level working, nor should it be necessary to use a wheel or skid.
5. Do not worry if the plough does not run level at the first attempt. It may be fine-tuned to achieve level running as shown in "Operational Adjustments", numbers 3 and 4.

OPERATIONAL ADJUSTMENTS 3

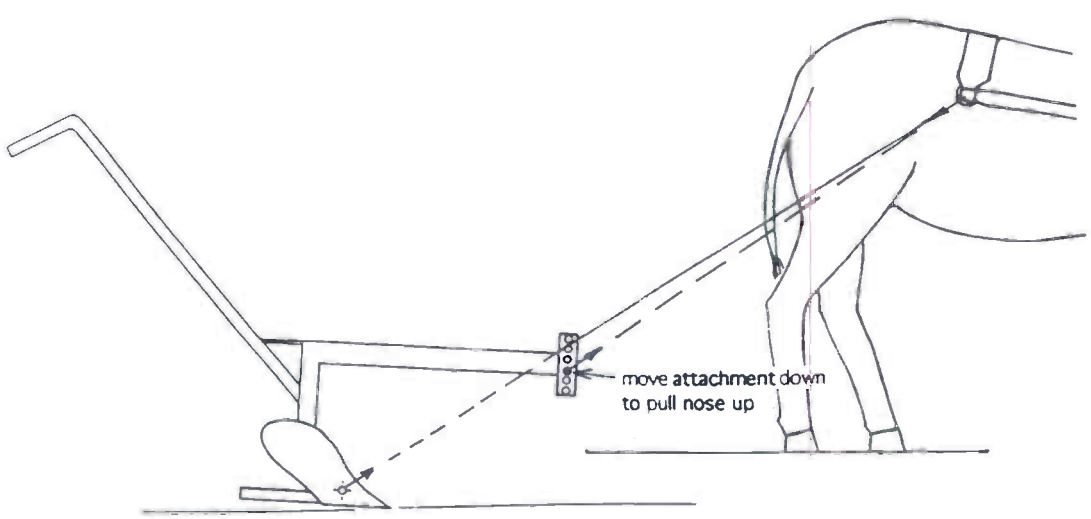
ADJUSTING THE PLOUGH IF IT RUNS NOSE-UP



Solution: Attach traces to a higher point on the regulator.
This will pull the nose down to meet the line of pull acting from the harness pulling point to the force centre

OPERATIONAL ADJUSTMENTS 4

ADJUSTING THE PLOUGH IF IT RUNS NOSE-DOWN



Solution: Attach traces to a lower point on the regulator.
This will pull the nose up to meet the line of pull acting from the harness pulling point to the force centre

CONCLUSION

The high-lift harness used in conjunction with a lightweight implement provides the opportunity to develop efficient, low-cost and user-friendly cultivation systems, particularly for single-animal operations.

The system's principles have been applied to the design of a breastband harness working with a 30º angle of pull and a lightweight plough for use by a single donkey. It has been extensively tested in the field in Scotland and Tanzania and also demonstrated in those countries and in Kenya, Ethiopia and England with god results. In Bolivia a brief trial by farmers at Sarco Bamba, in a moist silty soil of medium/high bulk density demonstrated its ease of adjustment and control with excellent stability in use. The plough was also used by a horse pulling at an angle of about 27º with similar good results — the draught was measured with a dynamometer showing an average draught of about 38 kg (380 N). In practice a slightly larger plough would be designed for use with a horse.

Harnesses giving a pull angle of 30º are reasonably easy to design and give good results (approximately half the draught compared with traditional harnesses pulling at 20º or less). It is suggested that this angle might be standardised and implements designed to match.

CIFEMA is currently building its own version of the single-furrow donkey plough and also of a donkey ridger, for trials and evaluation, using a 30º harness. Consideration is being given to the design of other implements in donkey and horse versions.

The author wishes CIFEMA every success in the whole range of its activities.

APPENDIX

EQUIPMENT PECIFICATION AND COMMENTS

HARNESSES

A1 Donke

Th fo ing specificatio for donkey harness as dr up at eetin ary th de led hanges de uary esul of expe gained wh fitting usin the first prototype The firs protot pe harness made from canvas material th bbin straps abou 30 mm wide and gs bou 50 diameter Othe itab materials be used ccording to ailab ity

SPECIFICATION

Breastband

Br tba width ength 80

Rings be attached tsid of br ba 70 betw ce tres.

B tba ha internal fill ng of sponge ther ft terial, with tw lin of lon itudi al stitchin to hol it place

hou der stra

Pad idth length padded internall

Strap ong, fixed to breastban end, other end ooped through the second breastband fastened by buckl Loops the pa all to be posiuoned sliding along the strap ckle sh be ged rest top of pad.

'Iip strap

Pad dth cm, length

p: 70 cm long, fixed to of th fl nk rings, looped thro gh the seco ank trace and faste ed by ckl Loops the pad allow be pos oned by slid it stra buckl sh ul be arranged to rest top he

Flank traces (two traces)

Length 120 cm with a trace ring attached at rear end. Free end looped through breastband ring and fastened to a buckle sewn onto the outside of the trace.

Pull traces (two traces)

Made from rope, spliced directly onto the rings of the side traces with the other ends tied to the swingletree fittings.

Swingletree

Made from strong straight-grained hardwood, 65 cm long, with central fitting (eyebolt or ring) for attachment to the implement and two fittings at 55 cm spacing for attachment of the pull traces.

A2 Horse harness

The following guidelines for manufacture of a horse harness were agreed on 23 January:
It should be similar in concept to the donkey harness but with 12 cm wide breastband and pads. Other dimensions to be determined by measurement of typical horse(s). The angle of pull should be about 30º to 33º.

B MOULDBOARD PLOUGHS

B1 Donkey plough

The prototype donkey plough manufactured in CIFEMA's workshop (16-22 January) performed well in brief field trials with donkey and horse on 23 January and it was agreed that this design should serve as the basis for a small batch for more extended field trials. The design combined the plough body (frog, share/mouldboard and landside) of the green plough with the frame (incorporating a rectangular hollow section beam) of the blue plough, together with an adjustment to find the preferred handle setting according to user opinion. Its weight was 8 kg, *i.e.* the same as that of the green plough (blue plough = 9.5 kg).

SPECIFICATION

It was agreed that the specification should be the same as the prototype plough with the addition of the following changes:

- the share and mouldboard should be separate parts, rather than the combined share/mouldboard as at present

  the share should be made from high carbon steel (*e.g.* old plough disc or leaf spring) to improve its wear resistance

  the handle should be in a fixed position as decided by farmer opinion. The wooden plough handle should be less thick, making it easier to hold.

COMMENTS

Design of the plough frame

The beam of the CIFEMA prototype plough frame was made from 50 x 25 x 2 r.h.s. There are a number of factors to consider when deciding between a frame made from r.h.s. and from 40 x 10 flat section as used for the frame of the green plough, *viz*:

Ease and cost of manufacture

The r.h.s. frame (excluding the hake plate) is made from 4 pieces of steel which must be cut and welded. At 2 mm the wall thickness of the r.h.s. section is rather thin for arc welding, which must be undertaken carefully by a skilled welder to avoid weakening it by burning In contrast the flat section frame is made from one piece of steel which only requires localised heating and bending, minimising the skill and cost of manufacture.

Strength

The frame made from flat section steel was designed with a factor of safety between 4 and 5 when used by a donkey so that strength should be sufficient for work in tough conditions. The r.h.s. member is about twice as strong in bending — extended field trials would show whether the extra strength is needed in practice.

Ease of repair

If necessary it would be easier for the flat section frame to be repaired by local craftsmen. It is suggested that a small batch of each type of frame (say five of each) should be made. Their manufacturing time and cost should be compared and extended farm trials should be made of both types.

Use of the frame as a basis for a multi-purpose implement

As manufactured at CIFEMA the plough body was attached to the frame by two bolts, giving interchangeability to allow fitting of a ridging body as an alternative. A bolted arrangement tends to work loose in everyday farming conditions and the holes quickly elongate so that retightening the bolts becomes less and less effective. Accurate manufacture and maintenance helps to reduce this problem — in particular each set of bolt holes must be positioned with a high degree of accuracy, the bolts must fit very closely in their holes and they must be kept well tightened.

This potential problem might be reduced by attaching the plough body using three bolts rather than two. The situation must be kept under close review and an alternative more secure fitting method devised if it proves necessary. Ideally this should prevent any relative movement between body and frame, not involve the use of a spanner or other specialised tool and should not be affected by dirt.

B2 Horse plough

The donkey plough worked well when pulled by a horse, but with little obvious increase in actual work done. The horse probably pulled at a greater speed (not measured) but the measured draught was only slightly greater. Presumably there was an associated slight increase in working depth, although this could not be judged by sight and no measurements were taken. It was agreed that trials using a horse to pull the donkey plough fitted with a 6" mouldboard had demonstrated the potential for producing a purpose built horse plough.

SPECIFICATION

The following outline specification for a horse plough was drawn up:

Plough body and frog

The whole of the plough body (frog, share and mouldboard) to be increased in size in the ratio of 3:4, compared with the donkey plough.

The share to be a replaceable component about 60 mm in width, separate from the mouldboard and made from high carbon steel heat treated to improve wear resistance.

The landside to be made from 50 x 10 flat steel, 450 mm long in the first instance (as on the existing donkey plough) with the option of extending it to 600 mm length if field trials suggested this might improve performance/controllability.

The plough body to be built with a side suck of 2 to 5 mm, *i.e.* vertical edge of the mouldboard should extend this distance beyond the face of the landside.

Frame

Existing frame dimensions to be maintained subject to acceptable performance in field tests. If an increase in size is considered desirable, care must be taken in locating the hake to ensure compatibility with a 30º pull angle.

Handle setting according to farmer preference.

COMMENT

In designing a horse plough the first matter to settle is the target draught. Based on a body weight of about 350 kg and a pull/weight ratio of 12% a horse should be capable of working continuously against a draught of about 400 N (compared with 200 to 250 N for a donkey). When deciding how to achieve the desired increase in draught a balance must be struck between a variety of interacting factors such as implement size, strength, weight, field performance, controllability and angle of pull. The author believes, based on field experience with the donkey plough and the underlying theory behind it, that the extra draught available form a horse should be used to increase the width of cut to about 165 mm (6.5"). This should lead to an increase in the area rate of work of about 44%, or more if the working speed is increased, together with some increase in working depth. The target weight should be about 12 kg with a pull angle of 30º, which gives opportunity for increasing the frame strength to deal with the higher working loads and also for increasing the frame size to give more under beam clearance to assist in dealing with surface trash. In this case it is suggested that the wall thickness of the r.h.s. used for the plough beam should be increased to at least 2.6 mm or, for a frame made from flat section steel, the section should be increased to 50 x 12.

C1 Donkey ridger

The ridging body bolted to the donkey plough frame performed well in the freshly prepared loose soil of the trial field, providing a nicely balanced implement for use with a donkey.

Minor changes were agreed as follows:

Mouldboard shape:

Lower edge to be reduced by 3 or 4 mm to reduce soil pressure leading to reduced penetration. Upper edge to be increased by 2 to 3 cm, with pronounced curvature, to reduce the quantity of soil over-riding the body. The changes to be blended in to make a smoothly shaped mouldboard.

Keel plate

The keel plate with attached fin to be positioned with its lower edge about 8 to 10 mm above the plough point to give good clearance and arranged to be parallel with the plough frame.

Width adjustment

Adjustable mouldboard stays to be hooked onto a vertical post and retained by a hairclip type fastener.

C2 Horse ridger

A horse-pulled ridger to be built based on the donkey-pulled ridging body scaled up in the ratio 3:4, bolted to the frame for the horse-pulled plough.

APPENDIX 4

SUGGESTED RESEARCH TOPICS

1 A survey of farmer opinion on the use of various animal/implement combinations now and for the future

BACKGROUND

The use of a pair of oxen pulling a long-beam cultivation implement is traditional in Bolivia and is supported by availability of a variety of equipment made by farmers, by local artisans or in factories. What is the farmers' attitude to the use of other animals and equipment for their farming activities, assuming that alternatives which are potentially viable, technically and economically, are available or were to be made available?

It is difficult for farmers to make a balanced judgment because they are largely unaware of alternative equipment, and of its costs, capabilities and ease of use (or otherwise). They are also likely to have an instinctive enthusiasm for glamorous equipment which is attractive but unattainable on any realistic technical and/or economic reckoning. Thus most farmers would like to own and use a tractor, although this cannot be justified on any rational assessment using realistic technical, financial and infrastructural criteria, except possibly in a few cases. Any survey conducted must guard against bias from these factors.

OBJECTIVES

To conduct a survey of farmers, grouped according to farm characteristics (topography, soil type, climate and other selected factors), in order to:

- determine availability of farm power sources — human, donkey, horse, oxen, tractors — and of implements used with them;
- determine the extent to which these power sources and implements are used;
- identify constraints on the use of underutilised power resources — lack of suitable equipment, shortcomings in existing equipment, *etc*;

To discuss, with randomly selected farmers, the potential for using those power sources which are currently underutilised, identifying the equipment (*e.g.* harnesses and implements) required for efficient execution of particular operations;

To assess:

- availability of equipment;
- user-friendliness (need for training, infrastructural back-up *etc.*)
- technical and economic viability for the specific farming circumstances;

To propose measures needed to encourage development of improved mechanisation systems (animal and/or tractor powered) technical and economic steps which would lead to desirable and sustainable developments, paying attention to the skills and resources currently available to the farmer (including financial resources).

To identify equipment which equipment CIFEMA might manufacture itself (*e.g.* implements and machinery) or under contract (*e.g.* harnesses), to assist in mechanisation development;

To identify the support which CIFEMA should provide to the farmer, *e.g.*;

- information and advice service;
- training;
- instructional material such as leaflets on selection, adjustment and operation of equipment (produced in pictorial format?).

2 An investigation into the use of ballast to control the draught of a donkey plough

BACKGROUND

The Tillage Implement Draught Equation (TIDE) indicates two methods by which the fundamental draught of an animal-pulled plough may be changed:

- by changing the angle of pull;
- by changing the effective vertical force (e.v.f.) acting on the implement.

Field experiments have confirmed the predicted effect of varying the angle of pull, *viz* that raising the angle of pull causes a progressive reduction in implement draught, but the effect of varying the e.v.f. has not been subjected to such rigorous investigation.

It has been shown that an 8 kg plough used in conjunction with a high-lift harness (30º angle of pull) generates a draught which is well within the pulling capacity of relatively small donkeys — larger donkeys could possibly do a full day's work against a rather higher draught load. The TIDE suggests that the draught could be increased by increasing the e.v.f., for a given angle of pull. The e.v.f. could be increased by ballasting the plough, hence it should be feasible to vary the plough draught incrementally. This might provide a user-friendly way of adjusting implement draught to match the pulling capacity of an individual animal.

The question arises — what level of draught can a single donkey sustain throughout a full working day? Published data is not very helpful, suggesting that donkeys can work against a draught force from 10% to 25% of their bodyweight, but the length of time for which these loads can be sustained is not specified. It is suspected that a donkey should be expected to pull not more than 15% of its bodyweight for a full working day, otherwise it is likely to tire rapidly.

OBJECTIVES

To investigate the effect of plough ballast on the performance of a high-lift harness/lightweight plough system, particularly the plough draught and depth of work.

To investigate the sustainable working draught of donkeys.

METHODOLOGY

The lightweight plough designed for use with a 30º high-lift harness weighs about 8 kg. Measure the plough draught, the depth and speed of work periodically for a period up to, say, 4 hours (taken as being a full working day) or until the donkey begins to tire. It will be necessary to define the criteria used to identify signs of work stress — heart-rate, respiration rate, temperature? Repeat with added ballast (1 kg at a time?), keeping other variables such as soil condition as uniform as possible. Ballast should be added at the fore-and-aft position of the centre of gravity to maintain the balance of the plough.

Repeat for other soil conditions.

Does the use of ballast provide a user-friendly method for matching implement draught to the animal's capability? To what effect? It may be better overall for the farmer to use the animal with a comfortable reserve of pulling capacity. How much reserve?

What conclusions can be drawn on the draught which a donkey can sustain throughout a working day?

3 To investigate the optimum settings for two beam-pulled implements, and the extent to which farmers achieve them in use

BACKGROUND

Two popular implements in CIFEMA's range — the *arado de montaña* and the *arado combinado* are designed with a heel which is arranged to maintain their correct working alignment by pressing lightly on the furrow bottom when in use. It is possible (in fact it is quite easy!) to maladjust the implements so that they run with the heel well clear of the furrow bottom so that they are tilted up from their intended alignment. They then begin to act as bulldozers, rather than as implements which lift and turn the soil as their designers intended. Theoretically this is an inefficient operating mode, with greater draught, more wear of the share and less useful work done than if correctly set.

OBJECTIVES

To investigate how the draught and useful work of the *arado de montaña* and the *arado combinado* vary with their alignment in work.
To make a survey of farmer practice to determine how widespread is the problem of poorly set ploughs and whether it is of practical significance.
To formulate a training procedure to encourage best practice in adjustment and use of beam-pulled mouldboard ploughs and ard-ploughs, and to formulate proposals for putting it into effect.

METHODOLOGY

Define the selection criteria (soil, topography, rainfall, crops *etc*) for each implement and their intended purpose (soil bursting, turning, *etc*) and, guided by discussion with farmers, set up qualitative and quantitative indicators by which to judge the degree to which the purpose is being met.
Assess the performance of each implement at a range of settings, measuring the draught and other criteria adopted for this purpose.
Define the limits of acceptable performance in relation to misalignment of the plough bodies.
In the light of results so far, make a series of on-farm visits when the ploughs are actually in use and discuss adjustment and correct operation with farmers, making demonstrations as appropriate. Record and assess observations and opinions.
Suggest any action necessary — essential; desirable; helpful.