Final Technical Report
R7376: A practical decision support tool to improve the feed management of ruminant work animals:

Livestock Production Programme -Forest Agriculture Interface / Hillsides

Helping extension services to deliver science to farmers

Centre for Tropical Veterinary Medicine, University of Edinburgh, Scotland.

and

Proyecto Mejoramiento Tracción Animal (PROMETA), Cochabamba, Bolivia

Background

Deteriorating levels of food production and increasing demands for food have reduced food security amongst rural communities in poor countries. Draught animal technology can help alleviate this problem by improving timeliness and reducing human drudgery (particularly amongst women) of cropping activities (Starkey, 1994). However, draught animals compete for limited forage resources with other classes of livestock that are more directly associated with food production such as dairy and beef cattle. Improving the sustainable work output and the cull market value of draught cattle can result in improved food security of the rural poorer by:

1) Reducing the number of animals that need to be retained to replace culled draught cattle thereby increasing meat output.
2) Improving the sale value of draught cattle at the end of their working life.

The work demands placed on draught animals within crop-farming systems are seasonal. Frequently these demands are highest when feed resources are most limited both in terms of quality and quantity. Research into the nutrition of draught animals has shown that animals are able to tolerate the live weight losses (resulting from energy deficits) that occur during the working season if an effort is made to compensate for these losses during the non-working season (Lawrence and Pearson, 2000). Fall *et al.* (1997) have suggested that if the progressive deterioration in body condition of draught animals from season to season is avoided then work output can be sustained over several seasons and the market value at the end of an animal's working life is enhanced.

The dynamism and complexity of draught animal management precludes the effective use of current formats (e.g. tables of feeding standards) that become unwieldy and error-prone when more than a few, basic variables are considered (Dijkman and Lawrence, 1997). In many farming systems – e.g. the Middle Hills of Nepal (Thorne and Herrero, 1999), this approach has developed indigenously, with the strategic feeding of crop residues and supplements to draught animals during certain times of year. However, the pronounced changes in patterns of resource availability that are being observed in smallholder farming systems throughout the developing world mean that the need for an improved approach is rapidly becoming more critical.

DFID funded project R6282 (*The Development of a Practical Dairy Rationing System for the Tropics*) has demonstrated the utility of an approach based on the simple computer technology that is becoming increasingly common in the local or regional headquarters of extension services. DRASTIC (A Dairy Rationing System for the Tropics; Thorne, 1998) uses readily available data to run a quantitative biological model, the outputs of which allow trade-offs amongst alternative feeding strategies to be evaluated. Input data are characterised by simple, qualitative assessments of animal types and feed quality that are linked to the quantitative core model using artificial intelligence (AI) techniques (Thorne *et al*., 1997).

Recent field testing of DRASTIC in Bolivia and Tanzania (Thorne, unpublished data) indicates that the approach is robust and will be readily adaptable for use in the development of the proposed software for work animals. More unusually, interactions with farmers and extension staff during the course of this testing has confirmed that the information generated by this type of tool is effective in delivering improved technical support for the development of farmers feeding strategies.

Previous research work, conducted with DFID funding (R4810, R4902, R5198, R5926), on the nutritional and general management of work animals has shows the extent to which their more systematic and rational use could improve the livelihood of smallholder households in developing countries (Pearson and Dijkman, 1994). Furthermore, the considerable volume of quantitative information that has been generated by this research could, *if packaged appropriately*, underpin the development of appropriate strategies for achieving this. Most importantly, data allowing the responses of draught animals to variations in feed availability to be predicted are now readily accessible in summary form (Lawrence and Pearson 2000, 1998).

The key question is ‘What constitutes appropriate packaging for this information?’.

A number of issues need to be considered:

- Rationing work animals is normally undertaken in mixed-species livestock holdings in which they are not always the highest priority for the allocation of limited feed resources (Thorne *et al*., 1999);
- In some farming systems, work animals are multi-purpose animals (e.g. the draft cow). Where this is the case, the impact of work on other production functions needs to be considered as part of the process of planning appropriate feeding strategies (Starkey, 1994);
- Sustainable management of draught animals requires farmers, not only to match the current feed demands of their animals to the available feeding resources, but also to take account of past live weight losses and to predict future work demands (Fall *et al*., 1997).
- Quantitative input data for biological models are generally unavailable or so unreliable as to be useless at the field level.

OXFEED is a decision support tool, which was developed to address the above challenges. It has inherited the graphical interface of DRASTIC along with some of the underlying biological models and AI algorithms, but also incorporates features of the energy rationing system developed by Lawrence and Pearson (2000) for working animals. Its key features allow it to address several key challenges:

1. The interface is simple and intuitive with a layout similar to that of most other Microsoft Windows Applications.

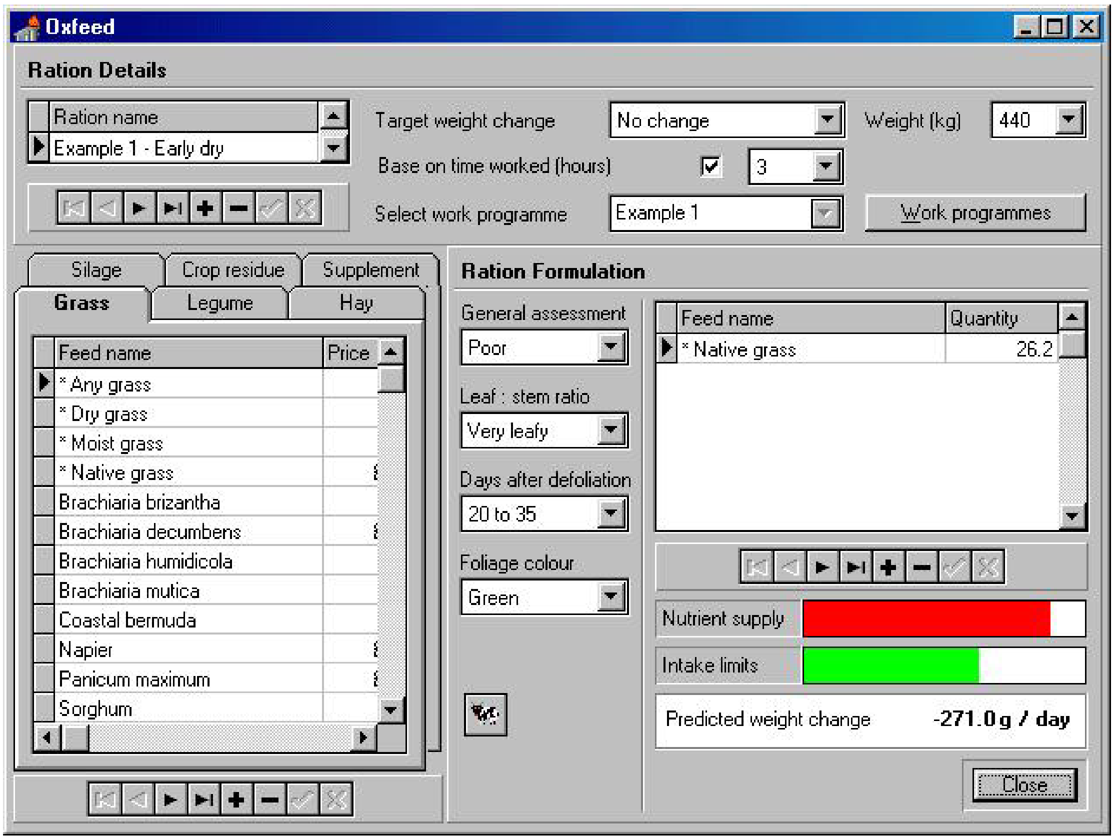

Figure 1: The OXFEED user interface

2. The data required to operate OXFEED is minimal and can be readily collected by extension delivery agents at field level with no specialised equipment.
3. The OXFEED interface allows scenarios to be tested and saved so that farmer's decisions can be readily tested on a cost/benefit basis.
4. The compatibility of DRASTIC and OXFEED provides the basis of a potential suite of similar DSS which could address the complex and dynamic challenges faced by poor livestock keepers.

The aim of the present project is to develop and test OXFEED within livestock owning communities that could derive direct benefit from its application. The geographical focus of this work is Central and South America within crop/livestock production systems. In particular the project is aimed at regions where an acute conflict between crop and animal production exists. The socio-economic focus is on sectors within rural communities whose livelihoods are becoming increasingly marginalised by land resource conflicts, and who do not have the financial resources to mechanise cropping activities.

The demand for this work has been clearly identified during the PRAs carried out during the preparatory phase of the project R6970. Previous research work carried out by CTVM, SRI, CIFEMA/PROMETA, ILRI and NRI focused on feeding strategies and management of draught animals. These studies have shown the considerable contribution that a more systematic and rational management of feed resources could make to livelihood security of smallholder farm households in developing countries (Fall *et al.* 1997). The development of OXFEED provides front-line extension workers with the means to formulated and disseminate science-based feeding and management strategies to the intended end-users.

Project Purpose

Improved performance of livestock (including draught animals) in forest-agriculture interface and hillside (crop/livestock or livestock) production systems.

The purpose of this project was the participatory development and field-testing of a user-friendly decision-support software (DSS) rationing package called OXFEED. OXFEED will assist front-line extension workers to make accurate assessments of feed resource availability and work demands on draught animals. The software makes use of biological relationships established by previous research and uses readily available data that was defined in consultation with farmers. The livelihood of smallholder farmers, who depend solely on draught animals for their agricultural power needs, will be improved through reduced expenditure on replacements, better timeliness and quality of work and increased income from the sale of finished/store animals.

Output 1.1: In-country PRA and socio-economic surveys

Farmer interviews

Farmer surveys were carried out in three communities within 60 km of Cochabamba (17º24’S, 66º09’W), Bolivia. Each community represented a distinct agro-ecological zone (Table 1), but all relied on draught cattle as the principal source of on-farm power. In all three districts cattle ownership was restricted to the animals required to provide power. However, oxen had a dual purpose role providing a source of on-farm power and a income from their sale as finished/store animals at the end of the cropping season. Few of the farmers in the study reared their own cattle, preferring to purchase sub-adult cattle from ranches at lower altitude.

Table 1: Description of the three communities surveyed in the OXFEED study

District	Community	Altitude (m)	Annual rainfall (mm)	Principal crops	Cropping system
Ayopaya	Piusilla	3800	647	Potatoes, oats, maize	Subsistence, extensive
Capinota	Sarobamba	2380	435	Potatoes, maize, alfalfa, vegetable cash crops	Commercial, intensive
Tiraque	Colque K'oya	3580	531	Potatoes, beans, barley oats	Subsistence, semi-intensive

Plate 1: Piusilla in Ayopaya district

Plate 2: Sarobamba in Capinota district

Plate 3: Colque K'oya in Tiraque district

From each community, 10 farmers were selected to take part in the survey, each being interviewed on four separate occasions during the course of the year long study (August, December, March and June). The interviews were conducted in order to elicit information on i) farmers' objectives for keeping animals, ii) current feeding practises, iii) indigenous systems of feed evaluation, iv) farmer and animal feed preferences and v) farmer perceived requirement for information. On the occasion of the first interview, farmers were asked to estimate the live weight of their animals, if they felt able. Each of the farmer's animals was then weighed using a portable weighbridge to determine the actual live weight.

Survey Results

Feed availability, feeds preferred by farmer and feeds preferred by animals
The available feed in each of the three districts during each of the four survey periods is shown in Table 2. There was seasonal variation in the availability of all feeds (with the exception of alfalfa in Capinota district). In all three districts there was some reliance, for at least some of the year, on cultivated forage crops. The cultivated forage crop varied between districts with oats (either fed fresh or as hay), maize and improved pasture grown in Ayopaya district, alfalfa grown in Capinota and oats and barley grown in Tiraque. With the exception of alfalfa in Capinota, these cultivated forages where only available for two out the three survey periods. At other periods farmers relied on native pasture or crop residues to feed their animals.

Table 2: Comparison of the feeds available in each of the survey districts during the four survey periods (n = 30).

		Number of farmers using feed			
District	**Available feed**	**August**	**December**	**June**	**March**
Ayopaya	Cut and carry improved pasture				1
	Fresh oat forage				2
	Grazing on improved pasture	1	2		
	Native pasture		8		4
	Oat hay	2		1	
	Oat hay and maize stover	7		8	
	Potatoes haulms and green forage maize				3
Capinota	Fresh alfalfa	3	8	4	5
	Maize stover	4			
	Maize stover and fresh alfalfa	3		3	
	Sweet potato haulms			2	1
	Vegetable crop residues		1		3
Tiraque	Barley straw	2			
	Fresh barley forage		3		
	Native pasture			1	
	Oat hay	1		6	
	Potatoes haulms		7		7
	Potatoes haulms and fresh forage oats				3
	Wheat or oat straw	7		2	

Table 3: Comparison of the feeds that farmers preferred to feed in each of the survey districts during the four survey periods (n=30).

		Number of farmers			
District	**Feed**	**August**	**December**	**June**	**March**
Ayopaya	Fresh oat forage			1	
	Grazing on improved pasture		6	5	6
	Oat hay	9	4	4	4
	Oat hay and maize stover	1			
Capinota	Fresh alfalfa	10	9	9	9
	Fresh oat forage		1	1	1
Tiraque	Barley straw	1	1	1	1
	Fresh alfalfa		1		1
	Fresh oat forage			1	
	Oat hay	9	8	8	8

Farmers within each district had strong preferences for a particular feed during a particular season (Table 3) despite the diverse range of feeds available (Table 2). In majority of cases the most preferred feed was cultivated forage or improved pasture; crop residues were only rarely chosen (5 out of 120 cases) as preferred forages. These preferences for these feeds were not related to the availability, with preferences changing little throughout the year. According to the farmers interviewed the feed preferences of their animals also varied little between survey periods (Table 4). The first preference of both farmers and animal showed a strong tendency to be the feed of highest nutritive value in that particular district indicating that this factor was more important than other factors that may have influenced their preference such as ease of feeding or quantity available.

Table 4: Farmers perceived view of animals feed preferences in each of the survey districts during the four survey periods (n=30).

		Number of farmers			
District	**Feed**	**August**	**December**	**June**	**March**
Ayopaya	Alfalfa		2		2
	Improved pasture	2	5	6	5
	Oat hay	8	3	3	3
Capinota	Alfalfa	9	9	9	9
	Maize stover	1	1	1	1
Tiraque	Barley, wheat or oat straw	1	1	1	1
	Oat hay	9	9	9	9

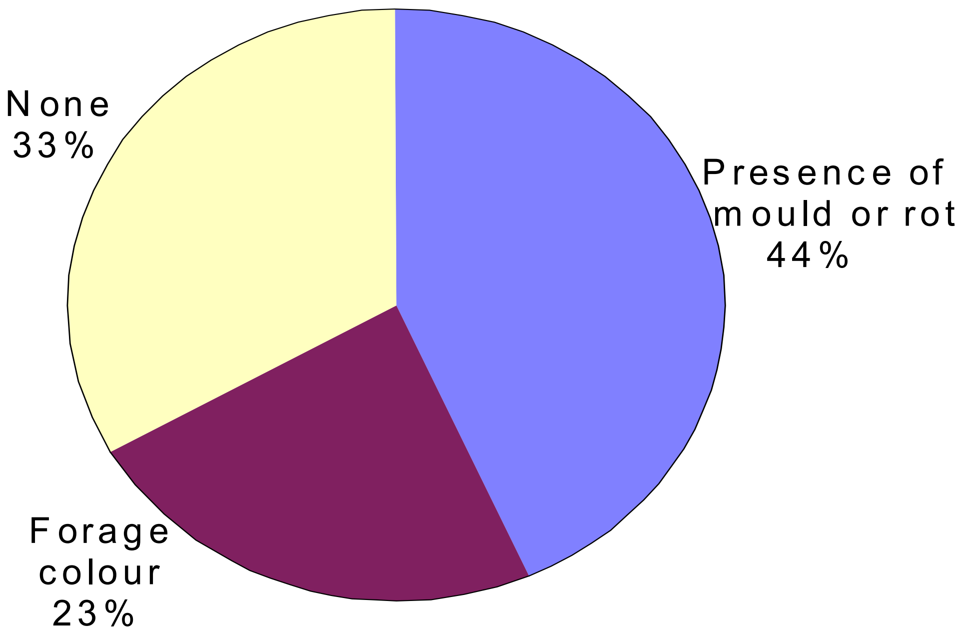

Figure 2: Method used by farmers to evaluate the quality of feeds

Although Table 4 shows that farmers were strongly aware of the feed of greatest nutritive value within their region, Figure 1 indicatives that farmers used only two methods of judging the feed they actually gave to the animal, these were the presences of rot or mould (44%) and forage colour (23%). A large percentage of farmers (33%) did not evaluate the quality of given feed at all.

Farmers' ability to estimate live weight

Less than 50% of farmers felt able to estimate the live weight of their cattle (Figure 3). When the farmers who felt able to estimate live weight were asked to judge the mass of their cattle, few estimated correctly (Figure 4).

This finding has important ramifications for the design of OXFEED. The underlying models of OXFEED rely on an accurate value of live weight; a large deviation from actual live weight will cause a large error between actual and predicted live weight changes. Most farmers do not know the live weight of their cattle and those who think they can estimate often provide inaccurate values. Extension agents using OXFEED to provide farmers with advice need an accurate method of estimating live weight. It is therefore necessary either to provide extension agents will accurate weigh-tapes designed for the cattle of the area, or train them to visually assess live weight more accurately.

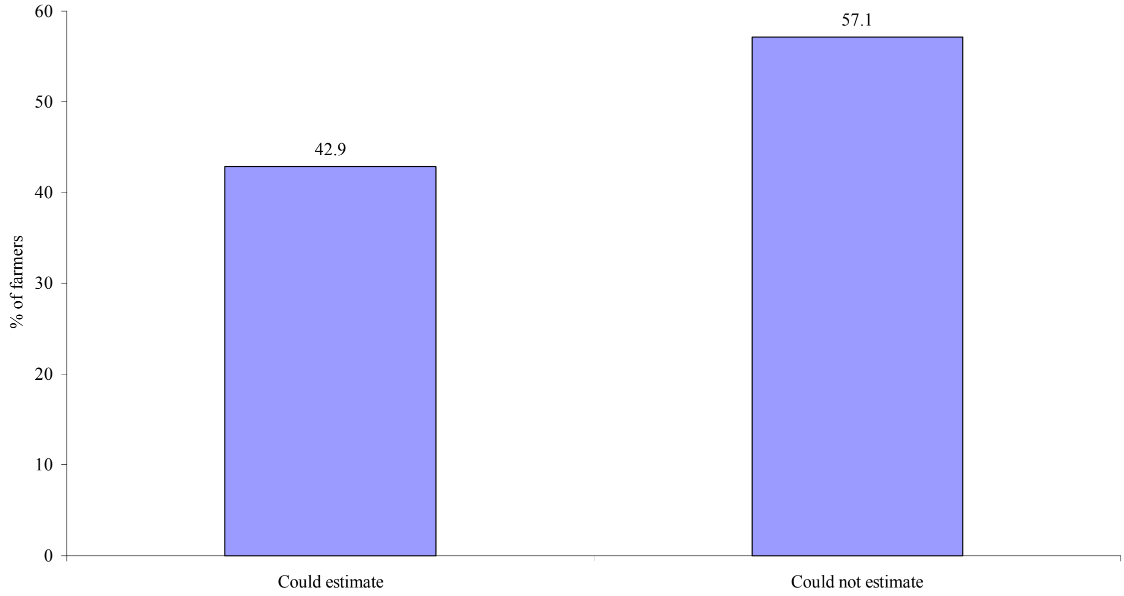

Figure 3: The percentage of interviewed farmers who where able to estimate the live weight of their oxen in the three districts surveys (n = 30).

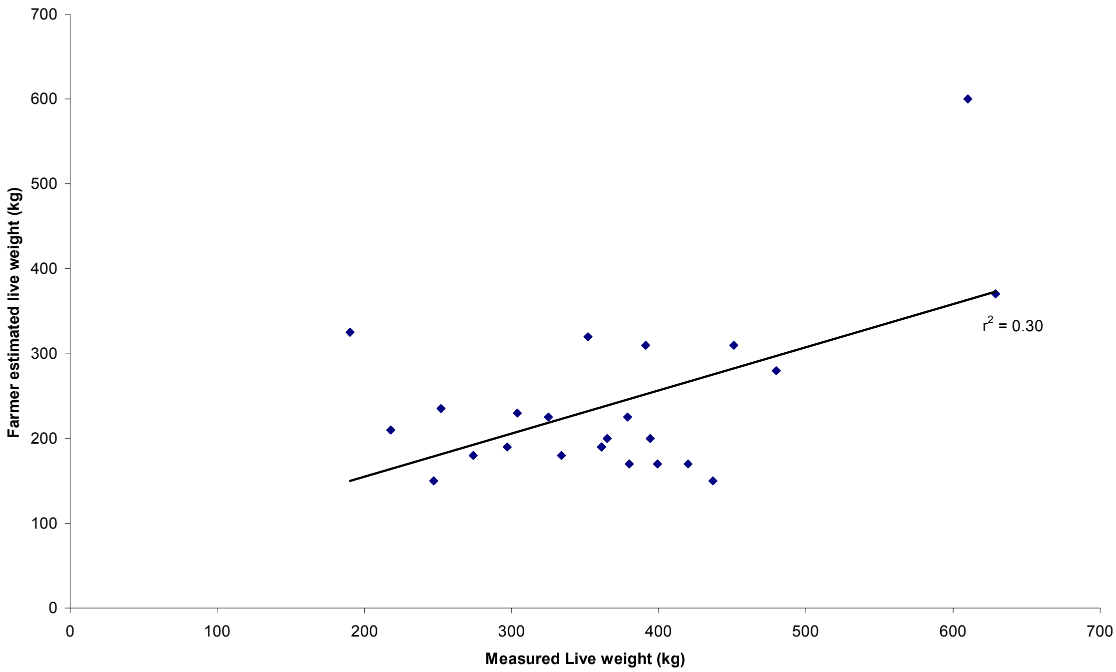

Figure 4: Relationship between measured live weight of oxen and their live weight estimated by their owners (n = 13)

Farmers' objectives for keeping cattle

The survey showed that principal reason for farmers keeping cattle was for the dual purpose of fattening and work (80%). Few farmers kept cattle solely for work more than two years (17%) and fewer still (3%) kept cattle solely for fattening (Figure 5).

The sale of fattened cattle is an important income for households and reduces the burden of feeding animals during parts of the year when there is little work. Moreover, this dual-purpose strategy helps offset the opportunity costs of committing scarce land resources to producing seasonal supplies of forage because it provides a direct income from the fallowed land.

The success of the production system for cattle in all of the three study districts is dependent on animals gaining weight over a farmer's period of ownership. It is therefore, crucial that farmers manage the available feed resources well on a day-to-day basis so that their long-term objectives can be obtained. OXFEED aims to provide farmers with information about the consequences of their decisions and to test scenarios without committing resources.

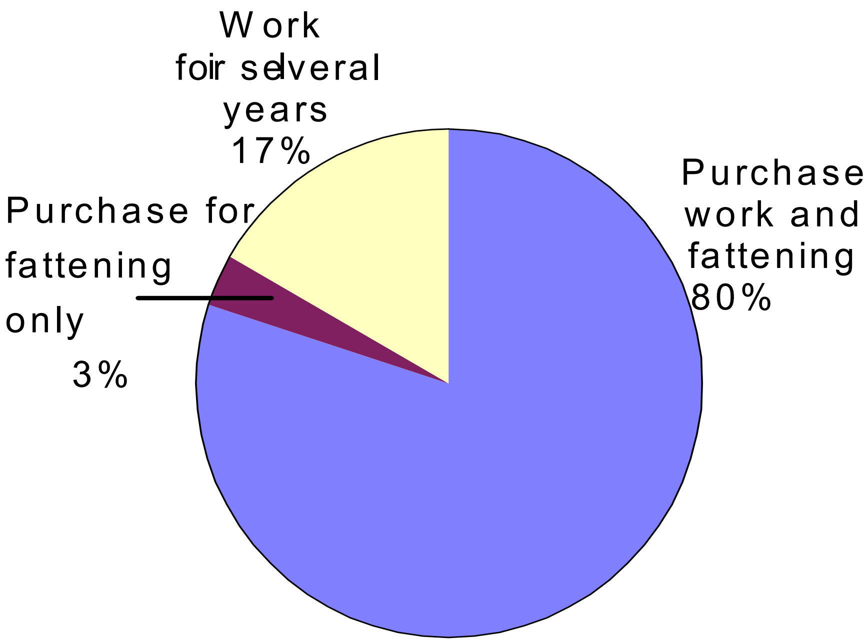

Figure 5: Farmers reasons for keeping animals in the three survey districts (n=60)

Information that farmers want from extension services
If OXFEED is to help extension agents address the problems that farmers face in this region of Bolivia it must be able to provide answers to the questions that farmers ask. Figure 6 provides a breakdown of the information requested by farmers during the survey. The priority of farmers in the three districts surveyed was obtain information on how to improve the work output of their cattle (52%), whilst others required information on how to formulate rations (28%).

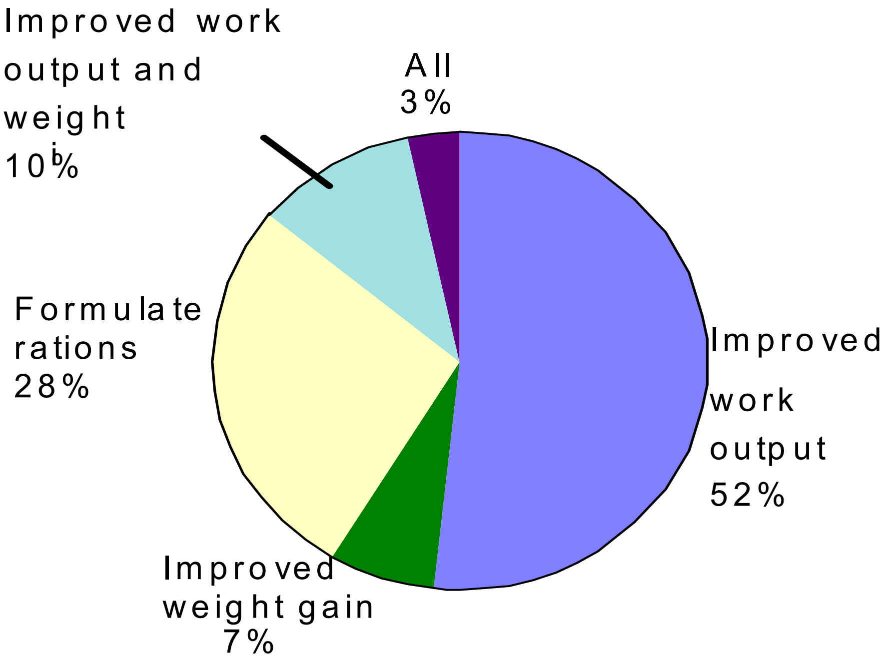

Figure 6: Information farmers want from extension services (n=60)

Summary

1. Farmers' first choice of feed is generally the feed with the highest nutritive value in that district.
2. There appears to be no indigenous method of feed evaluation.
3. Farmers are prepared to commit significant resources to fodder production in the integrated crop/livestock rearing system of the three districts.
4. Most farmers cannot estimate the live weight of their cattle accurately.
5. The objectives of keeping cattle in the three districts are well defined and production orientated; stakeholders are likely to be receptive to extension messages promoting improved productivity.
6. The information demanded by framers from extension agents can be provided by OXFEED or other similar DSS.

Output 1.2: In-country surveys to establish the institutional capacity of Bolivian Non-government organisations to use OXFEED computer software for draught animal development

Postal Survey

Preparatory activities carried out by project R7376 during its initiation included a postal survey of 120 non-government organisations (NGOs) involved in agricultural extension within all the administrative departments of Bolivia. The aim of this survey was to establish the capability of NGOs to use OXFEED in the dissemination and implementation of draught animal development initiatives. There was a positive response to the survey with 66% of recipient NGOs returning completed questionnaires by the end of January 2000. (See Annex 1 for a English translation of the postal survey)

Survey Results

The role of NGOs in draught animal development projects and their computer capability

Survey respondents were selected on the basis of their involvement with smallholder farmers. Survey results indicate that 76% of the respondents were or planned to be actively involved with draught animal development. All the respondents had computer facilities at their head and field offices (Figure 7). Head offices have an average of 10 (s.e. 2.2) competent computer users on their staff; at field offices the average number of competent computer users was 8 (s.e. 1.5). The most common operating system was Windows 95/98 (Figure 7).

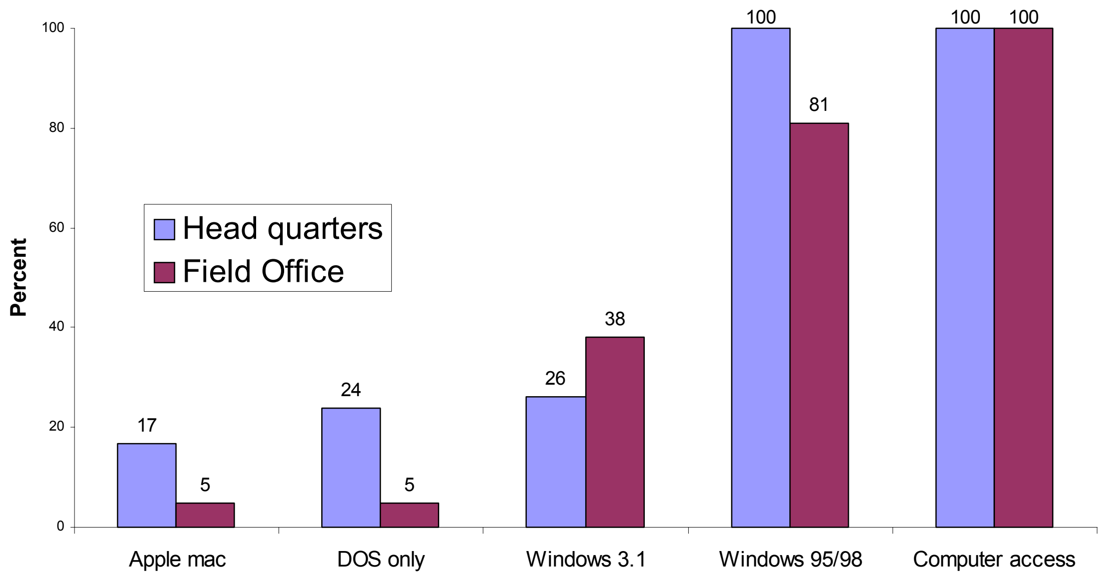

Figure 7: Bolivian NGO access to computers assess broken-down by operating system (n = 80).

Feasibility of the Proposed Software Dissemination Pathways

Although OXFEED is designed specifically for Windows 95/98, results from the current project indicate that all surveyed NGOs had access to this operating system. This gives users the inherent ability to download upgrades from the Internet either via email or Web browsers. The results from the survey indicate that there is wide spread Internet access at head office level (Figure 8). The feasibility of supplying upgrades of both programme and feed database files to NGOs, on demand, via the Internet was thus firmly established by the survey results. Once downloaded at headquarters distribution of upgrades to field offices would be via floppy disk.

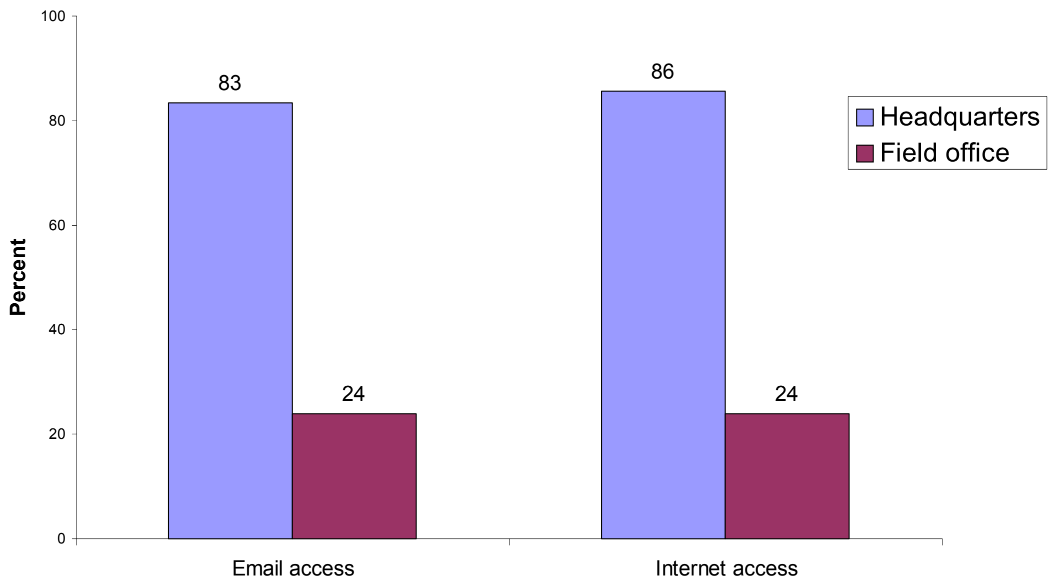

Figure 8: Bolivian NGO's access to email and the Internet at head quarters and field offices (n = 80).

Output 1.3: Delphi version of OXFEED

A Delphi version of OXFEED which could access the feed database and qualitative indicator features of DRASTIC was designed and constructed. The software was designed to operate with Windows 95/98. Minimum system requirements determined from the results from activity 1.1 and 1.2 were a principle design criteria along with the constraints imposed by the range of input data determined in 1.1.

The software is now available on the Internet in English and Spanish versions at the following web site www.stirlingthorne.co.uk. Both versions of the software is included in Annex 2 on CD-ROM. A Spanish instruction manual (funded by the DFID Advisory and Support Services Contract Programme) is included in Annex 3 (an English translation was not funded).

Output 2.1: Expansion of core feed database required to run the software

One of the essential pieces of information that OXFEED requires is the nutritive value of the available feed resources. Much of the published information on the nutritive value of feeds applies only to temperate situations or is not sufficiently detailed to allow calculations of metabolisable energy values.

Once baseline data is obtained OXFEED allows systematic modification of the feeding value of the available feeds according to quantitative indicators (QI) such as colour of forage, stem:leaf ratio, farmer perceived value and general quality (presence of mould etc). These QI are used to place currently available feed on a continuum between minimum and maximum expected feeding value for a particular feed.

The objectives of this phase of the project was to expand the OXFEED feed database and to test the efficacy of the QI.

A total of 96 feeds were collected from various sites around the world (Ethiopia, Mexico, South Africa and Zimbabwe) and given QI scores at the point of sampling. These feeds were then analysed and their ME values determined by calculation (see- Annex 4). These ME values were used as the basis for expansion of the OXFEED data base.

In order to test the efficacy of the QI *per se* to predict ME, binary logistic regression analysis was used to compare the calculated ME value of the feeds with the recorded QI score. The value of QI at predicting ME varied with feed type considered (Figure 9). Leaf:stem ration was the most value individual QI. Grass fodders (hays and silages), legume fodders and pasture were had QI with stronger correlations with calculated ME than the other fodder types considered. All the QI of some feed types (e.g. others) were not closely corrleated with calculated ME. Although the relationships between QI and ME are fairly poor (Figure 9), QI are only by OXFEED to modify ME values and therefore they still may have value in fine tuning the ME of currently available feeds. In order to test this a more detail analysis was therefore carried out using multiple regression in order that each QI could be weighted within the OXFEED algorithm.

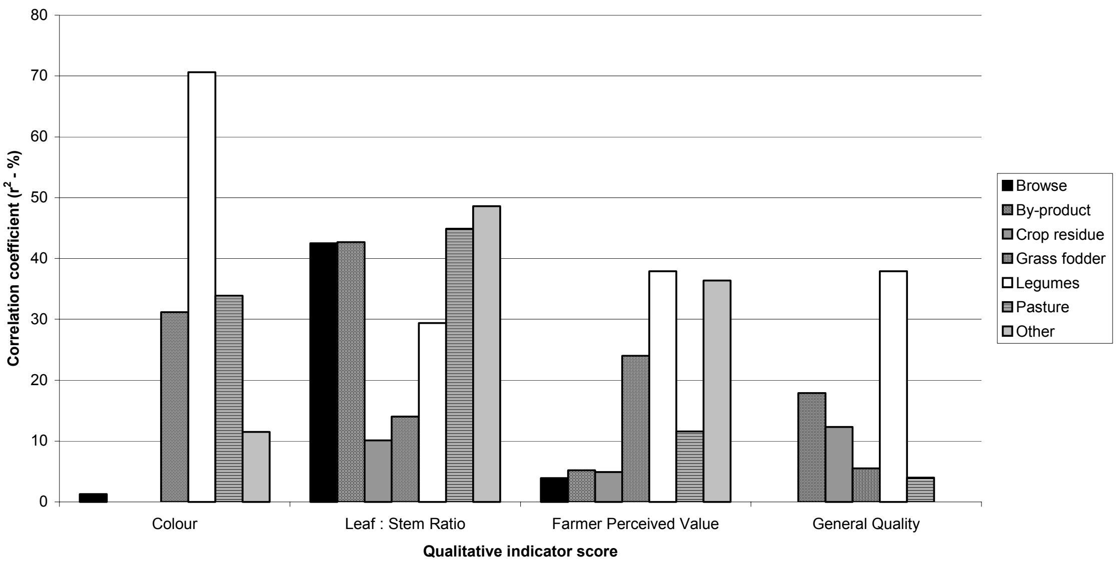

Figure 9: The relationship between qualitative indicators and calculated ME for 96 feeds collected in Ethiopia, Mexico, South Africa and Zimbabwe.

Multiple regression analysis using minimum ME (ME), feed type score (FTS), colour score (CS), leaf: stem ratio (LSRS) and farmer perceived value score (FPVS) as predictors of calculated ME produced the following equation:

$$\text{Calculated ME} = 1.06 + 0.7\cdot[\text{ME}] + 0.367\cdot[\text{FTS}] + 0.393\cdot[\text{CS}] - 0.12\cdot[\text{LSRS}] + 0.345\cdot[\text{FPVS}]$$

In this equation ME, FTS, CS, FPVS had a statistical significant relationship with calculated ME ($p<0.01$). The correlation coefficient for the overall equations was 0.41, indicating a statistically significant relationship ($p<0.001$) between calculated ME and the QI used in this equation.

This equation was used as a basis for weighted QI in the modified OXFEED program and tested with feed data collected in Bolivia (Output 2.2).

Output 2.3: Revision of the prototype software, based on the outcome of the field evaluation.

Field surveys

There were three objective of the 8 month field study carried out in this phase of the project:

1. To collect field data on feeding practice, work rates and oxen live weights that would be used within OXFEED to model monthly live weight changes.
2. To monitor real changes in live weight over the course of the study to compare with the values predicted by OXFEED.
3. To compare farmer perceived changes in live weight with that predicted by OXFEED.

The field studies were carried out within the same districts as Output 1.1, with 20 farmers from each study site included. Each farmers was interviewed once each month using the questionnaire shown in Annex 5. The live weight of each farmers oxen was measured during the interview (Plate 4).

Plate 4: Determination of ox live weight in Ayopaya district.

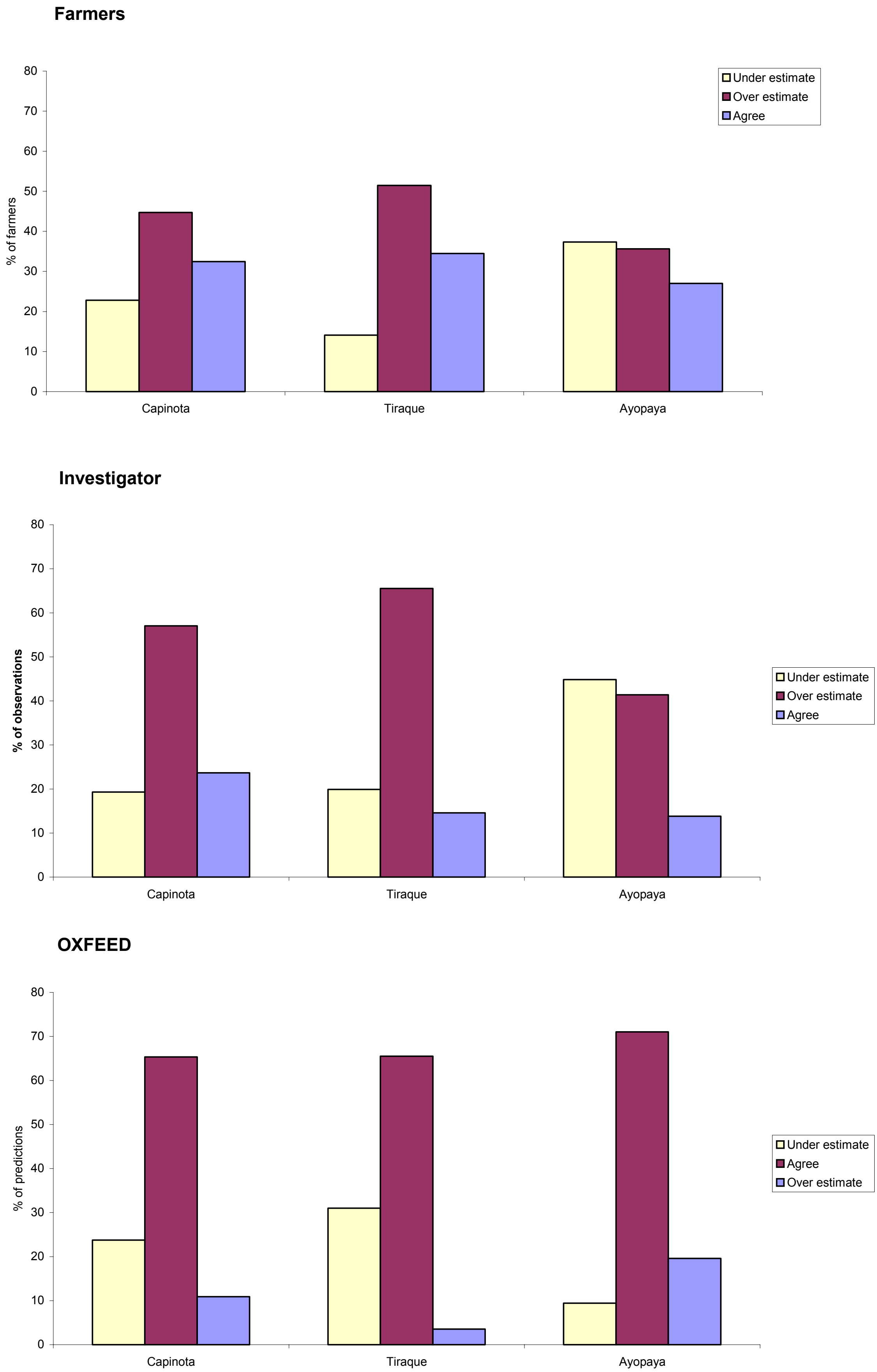

Figure 10: The accuracy of estimations of the direction of live weight change (increase, no change, decrease) made by farmers, investigators or by OXFEED in the three survey districts.

To investigate the sensitivity of OXFEED against the prevailing system of judging live weight changes each farmer was asked if their animals had either gained weight, lost weight or had not changed weight since the last interview. The investigator also recorded his judgment and prediction of live weight changes were made using OXFEED. These three estimates of the direction of live weight change were then compared to measured values. Numerical values provided by measured and OXFEED predictions of live weight change were categorised into three groups so that they could be compared to the categories used by farmers and investigators. The three groups were defined as:

1. Increase in live weight = monthly weight gain of more than 15 kg.
2. No weight change = monthly weight change of between –15 kg and +15kg.
3. Decrease in live weight = monthly weight loss of more than 15 kg.

The comparisons are summarised in Figure 10. In all cases OXFEED provided better estimations of the direction of live weight change than did farmers. In all three districts surveyed more than 50% of farmers could not correctly estimate the direction of live weight change. The estimates of direction of live weight change made by the investigators was intermediate to that of farmers and OXFEED. In Capinota and Tiraque there was a tendency for OXFEED to underestimate the direct of weight change (i.e. predict a decrease when there was either no change or an increase, whilst in Ayopaya OXFEED tended to over estimate the direct of weight change. These finding indicate that OXFEED provides a better estimate of live weight change than the existing system.

More details of the predictive abilities of OXFEED are shown in Figure 11. Live weight changes predicted by OXFEED closely followed measured live weight changes in all but two cases (both in Ayopaya); all other OXFEED prediction were within 10 kg of measured values.

Output 2.4:Preliminary study on the development of a weighing tape for Andean farmers.

During the field study the opportunity was taken to make a preliminary study of cattle to develop a weighing tape so farmers could estimate the weight of their cattle more easily. Animals were weighed and at the same time their heart girth and body length (from tail stock to base of the neck) was measured using a tape. Only 64 measurements were obtained but a highly significant relationship ($p<0.001$) was found between measured live weight and the two other biometric measurements.

The following preliminary relationship was established.

$$\text{Estimated Live weight} = 36.8 + 1.74 \cdot [\text{Body Length}] + 0.0041 \cdot [\text{Heart Girth}]^2$$

$r^2 = 28.5$; estimated live weight in kg, body length and heart girth in cm.

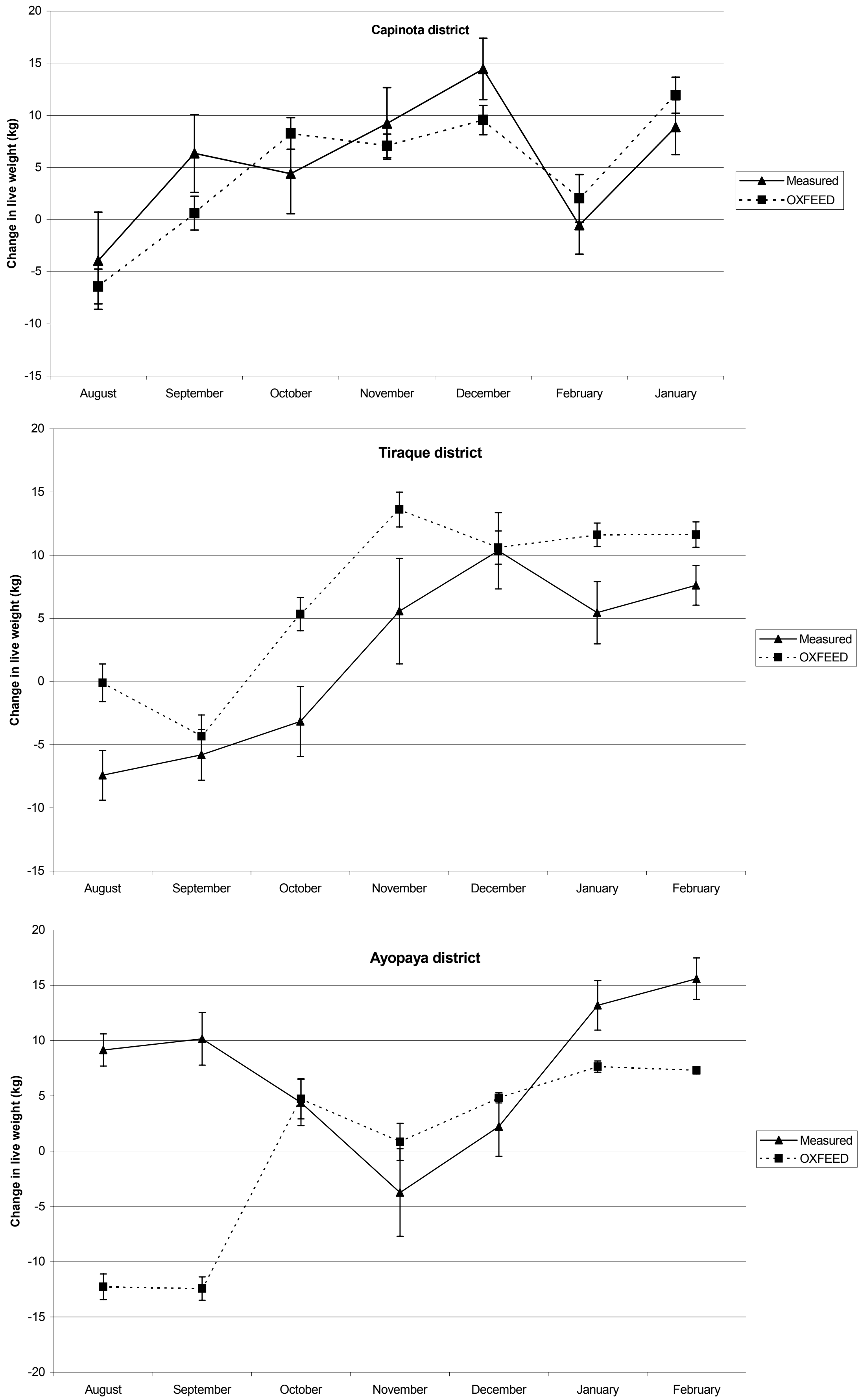

Figure 11: Measured live weight changes and those predicted by OXFEED in the three survey districts.

Output 3: Training of Front line extension workers in the use of OXFEED.

During the life time of the project two key PROMETA personnel were trained in the use of OXFEED. These two staff members now act as trainers-of-trainers and have held several workshops to train key extension staff through out Bolivia; up to April 2001 40 people from various NGOs have been trained (Plate 5 and 6).

Plate 5: Local NGO representatives being trained in the use of OXFEED, April 2001.

Plate 6: Local NGO representatives being trained in the use of OXFEED, April 2001.

Summary of Outputs

Outputs	Target date	Evidence
Decision support tool for rationing draught animals in mixed species holdings	Trial version of software available by September 2000	Software available at www.stirlingthorne.co.uk
Validated and field-tested software for planning draught animal feeding management in multi-species holdings	Tested version of software available by March 2001	Results in FTR, Draught Animal News, international journals.
A core of front-line extension staff in Bolivia trained in the use of the system	December 2000	Staff in place.
40 core extension agents trained to use DRASTIC/OXFEED in Bolivia.	Training workshop organised and extension workers actively using the software by March 2001	Research programme reports.
An interactive web site that allows users to download Spanish and English versions of DRASTIC and OXFEED from the Internet and get user support	Web site operating by April 2001	Internet site operating

Contribution of outputs
The market demand with in Bolivia has been well established during the course of this project, and PROMETA/CIFEMA are doing much to respond to this demand. Further funding from the DFID Advisory and Support Services Contract (ASSC) has facilitated the further extension OXFEED throughout Bolivia by adding on-line help facilities to OXFEED, holding workshops and through local cable television networks. Further support of these activities is essential at local level, particularly of local key staff.

The outputs are currently available to the intended end user. Dissemination within Latin America could be increased by publications within journals and popular development literature of the region.

OXFEED models require fine tuning to incorporate the findings of the final field studies.

ASSC has facilitated the further dissemination of OXFEED but further funding is required to promote the software in non-Spanish speaking countries, particularly in countries of the Indian sub-continent which have similar land use conflicts.

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