FINING CRITICAL MASS

THE CASE IN ANIMAL RESEARCH

Edited by
DOUG DANIELS and BARRY NESTEL

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Defining critical mass : the case in animal research. Ottawa, ON, IDRC, 1993. ix + 61 p. ill.

/Animal research/, /livestock/, /organization of research/, /resource allocation/, /personnel management/, /scientific personnel/, /research workers/, /developing countries/ — /budgeting/, /institutional framework/, /recruitment/, /wages/, /on-farm research/, /conference reports/, /lists of participants/, references.

UDC: 636.001.5:658.3 ISBN: 0-88936-649-7

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FOREWORD

The concept that there is a critical research mass, a minimum level of resources that must be available for a research activity to produce useful results, has been mentioned periodically in previous publications. There has not, however, been much concrete analysis of what would constitute a critical mass in any field of research. Given the lack of evidence by which to measure critical mass, it was decided to bring together a group of highly knowledgeable research managers to provide an "expert" judgment of what such a critical mass might be in one research field. Given the complexity and size of most animal research programs, it was decided to test this area first.

This proved to be a happy choice, for it was possible to assemble a group of experienced livestock specialists from different regions for this review. This was a difficult and unusual exercise, given the dearth of hard information on which to draw conclusions, and it is a tribute to the hard work of the group that it achieved such a broad degree of consensus on most issues in a few days.

The organizers want to acknowledge and express their appreciation to all the participants; this was a joint exercise in which all shared in the discussions and subsequent review of the first draft. Special thanks are due to Hugo Li Pun, of the International Development Research Centre (IDRC), who took an active part in coordinating the workshop. The support of the Inter-American Institute for Cooperation in Agriculture (IICA), through the involvement of Manuel Ruiz, and the excellent administrative support that IICA provided contributed greatly to the productivity of this workshop. Both Mary-Heather White and Lori Jones, research assistants at IDRC, assisted in preparations for the meeting. Claire Marshall contributed with her usual efficiency to the typing and preparation of this report.

Whereas there was a broad measure of consensus, most participants felt that this subject required much more analysis and more concrete case studies on which to draw conclusions. Thus, the participants saw their conclusions very much as guidelines to be modified according to the considerable variations in conditions that prevail in each country.

The findings are at such variance from the situation in many countries that this subject needs to be urgently addressed. Either the conclusions need to be significantly modified or refuted by more detailed analysis, or significant changes need to be introduced at the research-station level. Some suggestions for further research both IDRC and the International Service for National Agricultural Research (ISNAR) are interested in pursuing are made in this book. One particularly important issue that needs to be addressed is that of alternatives for those small countries not able to devote sufficient resources to develop a critical mass in their own national programs. All countries need to have access to new technology; when national resources are inadequate, other mechanisms such as regional research centres or regional networks must be explored. In some cases, it may be more a question of consolidating resources in few programs and stations or changing the relative allocation of resources.

Further work of this kind, which could improve the productivity of existing research systems, must now be given greater urgency. External donor agencies, which have provided a significant contribution to research funding, appear to be giving lower priority to supporting agricultural research at the same time that new demands for resources for Eastern Europe are diverting development assistance funds. Similarly, public funds in a number of developing countries are under pressure. The need to improve and demonstrate the payoff from research will surely increase. Policymakers and planners in both donor agencies and developing countries now appear to be questioning the rationale for further investment in livestock research. These questions relate to the magnitude of capital investments and current costs, the long lead time required for research, and the often disappointing results in productivity increases.

Changing the allocation of resources may not only remove many existing bottlenecks but also, and more importantly, enhance the morale and initiative of individual scientists who work in a very frustrating environment.

It is our hope that this exercise will contribute to such changes and provide a stimulus to further analysis and refinement of these concepts not only in animal research but also in other research fields.

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INTRODUCTION

A wide range of financial and human resources is used in any given research program, yet little information exists on what is an optimum level or mix of resources. Certainly, the lack of sufficient resources is frequently cited as a major constraint to livestock research in developing countries.

Examples can be found, particularly in Africa, where expensive and highly educated scientists are doing menial work because of a shortage of technical and support staff.

Some reviews of national programs have concluded that there has been too much decentralization of resources to small stations, resulting in subcritical groups of research staff. Recommendations have been to concentrate research staff in fewer stations and assign some of these small stations to alternative use. In other cases, the proportion of expenditure devoted to salary and wages is so high that there are almost no funds for operating expenses.

However, there is little to be found in the literature to suggest what resources are necessary to conduct an adequate livestock research program in any given set of circumstances. At the national level, some guidelines for investment in agricultural research have been suggested by international agencies. Except for those few countries where the private sector is able to capture a return from investing in agricultural research, this task now falls largely within the public sector. But there is little quantitative information available to guide public-sector planners and policymakers in ensuring that their investments in, say livestock research, are likely to be cost effective. This lacunae applies both at the national and at the research-station level. Thus, in allocating resources at the station level, policymakers have little to guide them with respect to issues such as

- minimal total staff and optimal staffing ratios (number of postgraduate professionals, ratios of researchers to technical support staff, etc.) and organization of staff (e.g., commodity versus discipline grouping);

- minimal total budgets and optimal ratios of funding for operational costs, information and documentation services, training etc.;

- evaluation of the efficiencies available through linkages (station to regional and international centres, between stations in different countries, etc.); and

- the role of contract and collaborative research.

One particular issue that has been increasingly mentioned in the literature is the concept of a critical mass of research resources: a minimum level of research resources necessary to have a reasonable expectation of producing useful results. It is a concept that has intuitive appeal; to take an extreme case, it is difficult to envisage that much would be produced in a research program like animal research that has no senior scientists or operating funds. It is, unfortunately, almost impossible to develop a more precise definition of "reasonable expectation" given the widely different kinds of research conditions and the serendipitous nature of research.

OBJECTIVES OF THE CONSULTATION

An effort to set some guidelines on this topic was made through an expert consultation that took place in San José, Costa Rica, from 23 to 25 September 1991. Participants included livestock and information specialists with extensive regional experience in Africa, Asia, and Latin America.

The objective of this meeting was to determine whether there exists a consensus that there is a critical mass of human and financial resources required to do different types of animal research and, if so, to determine the degree to which this critical mass can be quantified.

Given the difficulties of establishing norms in a field where there is so little information and so much variation in environments, some means had to be found in this short meeting to focus discussion and move beyond generalities. It was felt that it would be more useful to aim for a high degree of consensus and clarity on norms in one or two areas than to have a wide-ranging but inconclusive review of resources needed for all animal research.

Against this background, the consultation addressed two issues. The first was to try to define a "reasonable" level of resources for a sustainable livestock research program that could be expected to make a contribution to development.

To do this in a meaningful way, a typical livestock situation in a small, developing country was first described and quantified. It was recognized by the consultation that the conditions in many developing countries will differ from the typical country as it was defined. Thus, there can be no universal standards for resource allocations. However, the consultation felt that these guidelines would allow policymakers and planners to identify and question significant variations from the suggested norms. It was also decided to spell out the steps followed and provide as detailed a set of numbers as possible so that these could be assessed by others and modified where inappropriate.

Having defined such a country, participants then tried to develop an expert consensus on the resources required to conduct a "reasonable" livestock research program in that environment and to identify some ranges or ratios of resource requirements.

The second issue addressed was to try to define the extent to which the "reasonable" model could be reduced before the "critical mass" of resources became so small as to render neglibible the chances of mounting a worthwhile research program.

GENERAL REVIEW

The meeting began with a general review of the existing situation in developing countries. It was noted that the overall number of agricultural scientists in developing countries had quadrupled in the period from 1960–1964 to 1980–1985 (Table 1). Information at the subsectoral level, however, is much less complete. There was a sense that growth may have been less rapid in numbers of animal scientists than in numbers of crop-production scientists.

Concern about the adequacy of resources may seem surprising given the large increase in numbers shown in Table 1. However, these global numbers disguise the big variation in size between different national agricultural research systems (NARS). In more than 50 countries, the NARS in the early 1980s contained a total of fewer than 50 scientists (Fig. 1), many of whom are engaged in nonlivestock research.

Table 1. Total number of agricultural scientists (thousands).

Region	1960–64	1965–69	1970–74	1975–79	1980–85	Ratio, 1980–85: 1960–64
Sub-Saharan Africa	1.2	1.7	2.2	3.3	4.9	4.1
Asia & Pacific	5.1	7.9	10.6	17.4	22.7	4.5
Latin America & Caribbean	2.0	2.8	5.3	6.6	8.7	4.3
West Asia & North Africa	2.1	3.1	4.5	6.5	9.0	4.3
Developed countries	39.1	43.7	47.3	50.5	54.5	1.4

Source: Elliott and Roseboom (1988, p. 13).

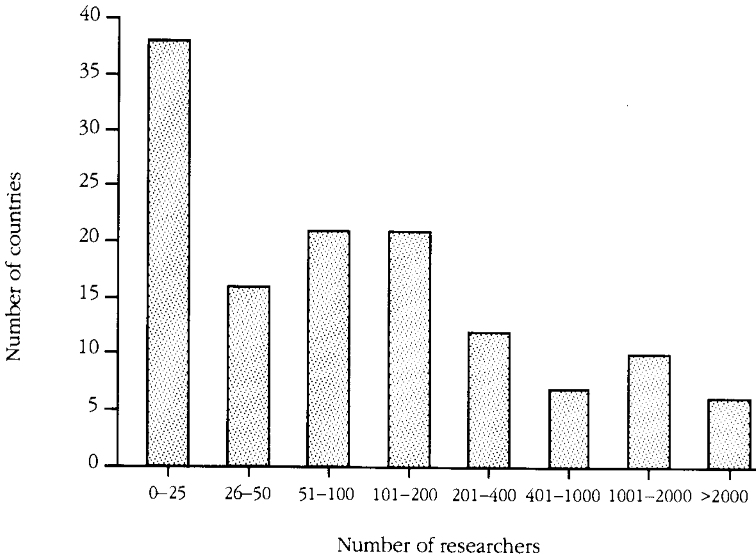

Fig. 1. The size of developing-country NARS (1980–1985 average) (source: Elliott and Roseboom 1988).

Whereas a number of these countries with small research systems will continue to add staff over time, there are some that may not be able to find the resources to develop a much larger research system. More than half of the developing countries have a population less than 10 million people, and the value of livestock production in many of these countries may not justify of a large research program.

Another cause for concern is the evidence that resources per scientist are declining in most developing regions (Table 2). Funding for agricultural research increased significantly over the last 25 years covered, but the number of scientists has increased even faster. At some point this unequal rate of development must represent a significant misallocation of resources.

The involvement of external funding agencies is a complicating factor in assessing the adequacy of resource use and in

Table 2. Expenditure per agricultural scientist (thousands of 1980 US$).

Region	1960–64	1965–69	1970–74	1975–79	1980–85	Ratio, 1980–85: 1960–64
Sub-Saharan Africa	104	121	119	105	78	0.75
Asia & Pacific	47	50	56	47	49	1.05
Latin America & Caribbean	85	89	84	99	82	0.96
West Asia & North Africa	53	52	68	56	39	0.74
Developed countries	52	68	77	81	87	1.67

Source: Elliott and Roseboom (1988, p. 13).

freely modifying resource distribution. Much of the growth in numbers of trained personnel has arisen through donor-assisted programs. These have also contributed significantly to the improvement of physical facilities and to the purchase of equipment. Operating costs have, however, largely been provided from national funds.

BACKGROUND PAPERS

Before addressing the issue of guidelines, the consultation reviewed four working papers.

The first paper (Cubillos et al. 1991) presented a case study of Guatemala. The main livestock resource is some two million head of cattle, which contribute 7.5% of the overall gross domestic product (GDP) or about a third of the agricultural GDP. Livestock research has a strong farming-systems orientation, and more than half the experiments are conducted on farm. In recent years, the research team has ranged from 11 to 16 professionals of whom 3 to 5 had postgraduate qualifications. Turnover of staff is high; five scientists — about one third of the total — left between 1985 and 1990.

Total funding has ranged from US $132 000 to $346 000 per annum in the period 1984–1990, with major year-to-year changes in both national and donor contributions. The latter component ranged from 18% of the total in 1984 to 69% in 1986. These large annual fluctuations in funding highlight the problem of sustainability in a system where, on average, yearly professional salaries were only US $3 023 in 1990. Fluctuations resulted in part from the declining value of the national currency and in part from variations in externally funded projects.

The second case study was from Botswana (Setshwaelo 1991), where populations of 2.8 million cattle and 2.7 million sheep and goats provide 90% of the agricultural income.

Because of the strength of the mining sector, agriculture's contribution to the GDP fell from 20% in 1975 to only 3% in 1990, although more than half of the population continues to be employed in agriculture. Livestock research tends to be commodity oriented and be on station with a large network of substations. A research team has been built up from zero in 1974 to a current level of 12 persons with postgraduate qualifications, 4 with Bachelor of Science (BSc) degrees, and a large support staff. Budgetary support has grown consistently and is now US $1.2 million a year, nearly all of it from the national budget. Salaries are four to five times those of Guatemala and there is little staff loss.

Botswana and Guatamala represent extreme variations in the average total financial resources available per professional with the average in 1990 being US $16 000 in Guatamala and US $77 000 in Botswana. If one ignores external funding, personnel costs represent 79% of the national research budget.

The third contributed paper (Broadbent 1991) dealt with scientific information needs for research; through examples it stressed the importance of the conceptualization and the specification of an information function for research. It is essential that an information system be flexible, so that it can be readily modified to suit the changing needs of researchers. For this to be feasible, there must be a feedback system, permiting information specialists and research scientists to verify information needs and flows. Such measures are necessary both to guide the analytical framework for the research and to ensure effective cost control. They imply that an adequately funded information system shall be a core element in any research program.

The final working paper (von Hildebrand and Nestel 1991) was based both on a desk study of literature regarding the resources deployed in livestock research in developing countries and on the responses to a questionnaire sent to selected contacts. Relevant information on human, physical, and financial resources and on some research outputs was obtained from 116 research stations in 30 countries. However, much of the data were incomplete and needed to be interpreted very guardedly. This made the data difficult to use as the basis for preparing guidelines for resource allocation.

The paper discussed some of the problems and issues of collecting data appropriate for the development of resource-allocation guidelines, particularly with respect to the type of data required, the time frame for collection, and the possibility of developing indicators of both input and output. It suggested that, to provide this type of information, a carefully planned field study would be necessary, as literature in this field is now very sparse.

THE RESOURCE-ALLOCATION PROCESS

The working papers were followed by a general discussion, which highlighted a number of issues.

1. It was felt that the research station is the most appropriate unit for identifying resource requirements for livestock research. It is at the station level where operating costs and the kind of research team that needs to work together can be most effectively calculated. Most published data on research resources are available only at the national level. Such data can be useful in determining what total level of resources should be devoted to livestock research relative to other areas of research. However, if resources are dispersed over too many research stations, then even a large national allocation for livestock research may mask inadequate disposition of such resources. In addition, detailed allocation of resources for operating costs can really only be effectively derived at the station level.

2. Most of the available information on resources allocated for research deals with aggregated figures for all types of research. Furthermore, research and development are often not clearly differentiated and so-called "research" expenditure often embraces development and service activities, so that actual research expenditure may be overestimated. Specific

information on livestock research inputs at the station level is hard to assemble.

3. Because livestock research does not represent a homogenous activity, any attempt to develop guidelines for resource requirements will need to develop a number of variations on that model. The complexity and development requirements of the livestock sector, the productivity of research scientists, and access to external research are some of the significant factors that need to be taken into account in assessing research needs at the national level.

4. Ideally, resources should be allocated on the basis of some cost–benefit analysis. Such data are, however, very sparse in terms of both ex-ante and ex-post analysis. Some work at the national level has being undertaken by the Australian Centre for International Agricultural Research (ACIAR) and ISNAR (Davis et al. 1987; Contant and Bottomley 1989; ISNAR 1987) but this analysis remains at the level of broad global calculations rather than the composition of the resource mix.

5. In the absence of guidelines based on cost–benefit analysis, several international organizations have suggested that resource levels for agricultural (livestock) research be based on the value contributed by agriculture (livestock) to the GDP. The usual level suggested is either 1 or 2%, although there is no empirical basis for either of these figures. In practice, many NARS operate at a figure closer to 0.5% once donor funding is discounted.

6. Most developing countries are faced with major financial constraints, and these need to be recognized in any modeling exercise. In such cases, an indicator such as 1% of agricultural GDP is of limited value, and it may be more useful to define the actual resources that can be deployed.

7. If scientists do not have adequate support staff or operating funds or if personnel are too widely dispersed geographically, the "critical mass" required to conduct effective research is unlikely to be available.

8. One conclusion from this type of analysis, which will not be palatable universally, is that some countries or stations may be too small to justify an animal research program. USAID (1985) has suggested that a NARS that has fewer than 8 to 12 scientists or that serves a commodity produced on less than 100 000 ha of agricultural land may not be viable. It is worth noting that in the von Hildebrand and Nestel working paper covering 116 livestock research stations, 33 had 5 scientists or less and 46 had 10 scientists or less. Other suggestions as to the minimum scientific staff recommended for a viable research station include Marull (1967a, cited in Nestel and Trigo 1984), who suggests 4 scientists; ISNAR (1983), 15 scientists; and Trigo and Pineiro (1984), who suggest 4 scientists with doctorates or a Master of Science (MSc) degree and 8 with a BSc.

9. Only Trigo and Pineiro (1984) dealt with the level of training, although this is an issue of interest to many developing countries. It has major cost implications for countries without facilities for postgraduate training, as the overseas training for an MSc now costs about of US $60 000; for a doctorate (PhD), US $100 000. In developed-country agriculture, about 70% of researchers have postgraduate qualifications. In developing countries, the figure, aggregated regionally, ranges from 30 to 60% (Fig. 2). In some countries, it is even higher (81% in Botswana).

10. The optimal ratio between scientists and support staff, particularly technicians, was another topic that aroused considerable discussion. In many countries, a shortage of support staff

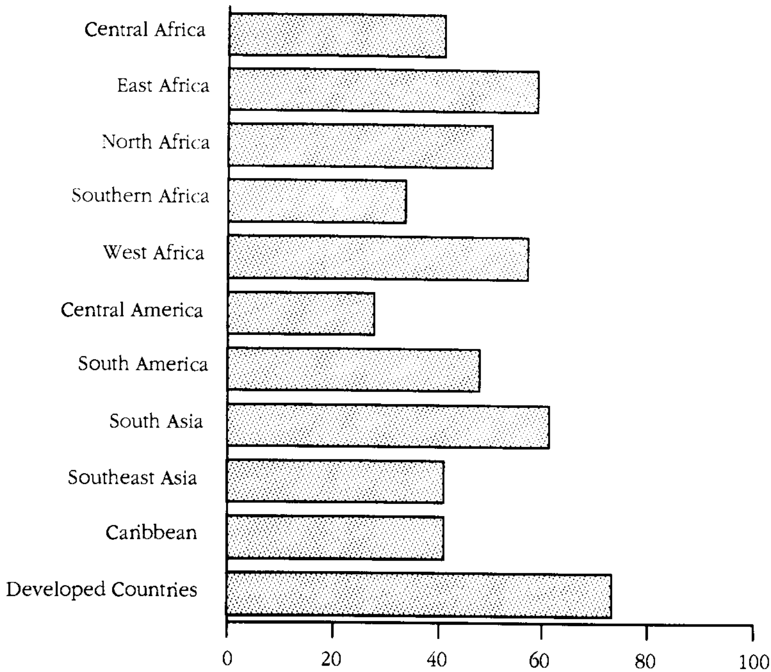

Fig. 2. Agricultural scientists qualification index, 1980–1985 (source: Elliott and Roseboom 1988).

results in trained scientists having to devote considerable time to activities that should and could be carried out by persons with fewer qualifications. Harini (1987) has suggested a desirable ratio of 10 support staff per scientist. Anteneh (1985) has recommended for Africa 15 junior assistants or labourers plus three technical assistants per researcher. It was suggested that the weaker a country's infrastructure of administrative services, transportation, and repair and service facilities, the larger the support-staff component should be to compensate for these deficiencies.

11. The optimum number of disciplines required in a research station will depend on the degree to which the

research is multidisciplinary. The consultation felt that few stations could afford to be without both biological and socio-economic expertise, although in many cases the latter was lacking.

12. In contrast to many of the other budget categories where information is very partial, there was a considerable volume of data on personnel costs. These costs frequently made up 70 to 90% of total research-station budgets. There was general agreement that when personnel costs exceeded 70% of total costs, there is a major risk that operational funds will be too low to operate an effective program.

13. Paradoxically, although personnel costs often represent a very high portion of the budget, individual salaries are very low. In some cases, they are so low that staff either take a second job or seek other employment. This situation often arises from a combination of low public-sector salaries and underemployment. Both of these factors act as disincentives to research productivity. Some efforts have been made to remedy the salary situation by creating a parastatal research organization where salaries are freed from public-sector norms; but this is often difficult politically, especially in countries with weak economies. Policymakers need to recognize that a sustainable, high-quality research system requires personnel with skills and incentives, which may imply a close, hard look at the structure of the research budget. It does not make sound economic sense to employ a large number of scientists and an even greater number of support staff, provide them with limited operational funds, and then expect a productive research program. Research does not come cheap.

In 51 countries surveyed by Oram and Bindlish (1981), only 14 had an average total cost per researcher of under US $20 000.

Some more recent figures are Botswana 1990, US $77 000 (Setshwaelo 1991); Argentina 1989, US $48 000; Chile 1988, US $60 000; Brazil 1989, US $112 000 (IICA 1991). There are also cases, however, such as Peru in 1990 (US $8 000) and Ecuador in 1988 (US $6 000) (IICA 1991) where expenditures per scientist are extremely low.

THE COUNTRY MODEL

Designing a livestock research program in any one country requires a complex calculation of many different factors, involving national objectives, the state and potential of the animal industry, and the difficulties and potential for research programs.

There are so many variables that it would be impossible to develop indicators for each of these different environments or to develop norms that could be applied rigidly across a large number of different environments. The best compromise may be to develop a limited set of indicators that relate to a fairly large range of countries. The expert group decided that it would be easier to develop guidelines for a research program in a specific small country. These guidelines could then be modified according to the different environments in different countries.

The group decided to estimate the resources needed for a hypothetical small country. The approach used was to

- outline the scope and key characteristics of the livestock industry in this country;
- define a program that would address a few key areas of research;
- identify the key disciplines that would be needed to develop these research programs;

- identify the numbers and levels of education of scientists, field staff, and administrative personnel as well as the physical facilities, materials, and supplies needed to operate these research programs; and

- used average cost estimates to identify the financial costs of the research programs defined; as explained later, this process was followed for two levels of research programs.

The basic features of the livestock sector in this small country were defined as follows:

- There is a population of 2 million dual-purpose cattle and 1 million sheep and goats, mainly on small farms.

- The annual offtake rate for beef is 12.5% (i.e., 250 000 head), with an average carcass value of US $350 (total beef production, US $87.5 million). The offtake rate for sheep and goats is 50%, with a average carcass value of US $20 (total mutton products, US $10 million).

- Of the cattle herd, 50% are adult cows with a 24-month calving interval, average lactation of 600 kg, and milk sold off the farm at US $0.20 per litre (total milk production, US $60 million).

- Hides and skins realize US $5 million annually. Thus, the total gross output from the livestock sector was about US $160 million. If we assume modest inputs are equivalent to 40% of output, then the net output produced by the sector will be US $96 million.

- Nonruminants are of limited importance, little locally grown feedstuffs are available for them and the use of imported feed is seldom economic.

The participants drew on the figures presented in the Botswana and Guatamala case studies presented at the meeting as well as their own experience in deciding on a livestock sector of this size. Subsequent analysis of the size of the cattle and sheep and goat herds in the countries surrounding these two case countries indicated that the figures were reasonably representative. In a sample of seven countries in each of Southern Africa and Central America, the average size of cattle herds was 2.2 million and the average size of sheep and goat herds were 1.4 million. The individual country figures are presented in Annex 1, Table A1. Table A2 presents a more complete review of the value of livestock production in developing countries.

THE REASONABLE MODEL

The consultation decided to look first at the kind of research program that might be considered "reasonable" or feasible in a small country where resources for research were likely to be constrained but sufficient for a modest and sustainable livestock research program capable of producing useful results. Resources must allow for an effective program able to generate appropriate technologies and maintain links with the international centres and national extension services. Given the difficulty of determining the probable payoff from research, it would be impossible to determine an optimum size for a research program. An optimum size might well be larger than the small program developed in this exercise; in any case, there are likely to be serious limits on the money available for livestock research. Despite repeated claims that agricultural research is underfunded, many countries are going to find it difficult to provide the resources suggested from public-sector funds. Thus, the consultation developed what might be called a resource-constrained, reasonable-sized research model.

The basic assumptions for the reasonable model were as follows:

- There is one central research station and three regional substations located in a total of two agroecological zones. The stations maintain a herd of 950 head of cattle for breeding and nutritional research.

- There are two main research programs, one to increase the efficiency of meat and milk production from dual-purpose cattle, the other to increase the productivity of small ruminants.
- Both research programs are multidisciplinary with an on-farm farming systems approach. There is a strong focus on technology adaptation rather than generation.
- As in many small countries and those with limited research budgets, the research strategy is based on applied and adaptive research and relies on support from other sources for more "upstream" and specialized inputs at the international level. These sources include collaboration with international agricultural research centres (IARCs), with donor-country institutions, and, through networking projects, with other countries in the region. At the national level, they involve subcontracting or cooperative activities with the Crop Research Institute, the local university, and, in some cases perhaps, with the private sector.

The consultation proposed a reasonable resource mix for a research station in these circumstances.

HUMAN RESOURCES

The consultation considered that the research station, to adequately fulfil its mandate, was likely to require a team of 20 professionals, at least 7 of whom should have a postgraduate degree. Table 3 shows six disciplines, each requiring one postgraduate scientist, with a seventh acting as team leader. The team leader's own discipline will be of less importance than his or her management and leadership skills. Each specialist would need to be supported by a junior scientist (BSc) and at each of

Table 3. Research program personnel for reasonable model.

Scientists	PhD, MSc	BSc	Diploma
Team leader	1	1	2
Nutritionist	1	1	2
Agrostologist	1	3	4
Socioeconomist	1	4	5
Range management	1	2	3
Animal breeding	1	1	2
Veterinarian	1	1	2
Total	7	13	20

the three substations there would need to be two additional junior scientists (a socioeconomist and an agrostologist or range-management scientist). It was felt that each of these 20 professionals should be assisted by a diploma-level technician, laboratory assistant, or enumerator.

Field labour and cattle care would require a total of 100 persons, mainly located on the main station. Station administration would consist of 5 persons at the diploma level (administrative, accounting clerk, librarian, farm manager, maintenance supervisor), 5 secretaries or computer clerks, and 10 cleaners or custodians.

BUDGET: PERSONNEL COSTS

Table 4 shows the total suggested costs for all human resources. Salaries shown are equivalent to levels that are now current or were recently in several countries in different continents. They are not the highest salaries paid in developing countries but represent levels of a sustainable system that would not be exposed to a heavy brain drain through lack of financial incentives. The unit costs shown include a supplement of 25–30% for benefits such as pensions and allowances. This

Table 4. Personnel costs (reasonable model).

Category	Number	Unit cost (US $)	Total cost (US $)
Researchers			
PhD	3	15 000	45 000
MSc	4	12 000	48 000
BSc	13	8 000	104 000
Diploma	20	6 000	120 000
Labour	100	1 500	150 000
Administration	5	6 000	30 000
Secretaries	5	3 000	15 000
Cleaners/custodians	10	1 500	15 000
Total			527 000

means that the annual base salaries shown are about US $11 500 for a PhD, US $ 6 200 for an MSc, US $4 600 for a diplomate, and about US $6 per day for a labourer's services.

These figures are obviously highly subjective — low for some countries and high for others. They must, therefore, be modified, country by country. However, when developing a country model, the participants felt it was particularly important to put in realistic figures for the professionals with postgraduate training as they are the key elements in assuming research quality.

It is noteworthy that the consultation felt that much of the work required in an applied research program could be carried out by diplomates and junior professionals, and that only 35% of the professionals needed a postgraduate qualification. This view is at variance with current trends in a number of developing countries, which seek to increase the number of postgraduate-trained personnel to a figure similar to that in developed countries (70%), where much more basic research is undertaken.

BUDGET: OTHER COSTS

Table 5 lists the group's assumptions for nonpersonnel costs. These are listed under nine categories.

Materials and supplies

The figures shown are suggested as realistic levels for the functioning of a sustainable operation. They are intended to cover supplies and purchases for experiments, drugs, chemicals, small equipment, computer supplies, stationary, etc. Norms of US $2 500 per scientist for research supplies and US $500 per scientist for office support are proposed. Many of those costs are for imported materials and hence would not vary as much as other categories from country to country.

Transport and travel

Given the on-farm nature of the research program and the existence of three substations, one vehicle per two scientists is suggested. It is proposed that a subsistence allowance be provided to permit each scientist to be away from base an average of 30 days a year. Limited provision is made for overseas travel (2 scientists out of 20 each year). These figures should be seen as indicative and are entered here to stress the importance of budgeting for such activities.

Repairs and Maintenance

This is a nominal figure.

Library, documentation, publications

Here again these indicative figures are presented to stress that these items, often ignored, should be seen as a vital component of the research budget if information is to flow both into and out of the research station.

Table 5. Nonpersonnel costs (reasonable model).

Category	Cost (US $)
Materials and supplies	
Research supplies ($2 500 per professional per year)	50 000
Office supplies ($500 per professional)	10 000
Station operations	
450 head of cattle, 400 sheep and goats; fencing, supplements, etc. ($30 per bovine)	15 000
Transport and travel	
10 vehicles (US $3 000 per year each)	30 000
Per diems (20 scientists × 30 days @ US $25)	15 000
Conferences, etc.	5 000
Repairs and maintenance	
Physical plant, equipment	15 000
Library, documentation, publications	
Books, journals	10 000
Annual report, monographs	5 000
Utilities	
Phone, electricity, water, etc.	15 000
Training	
1 new PhD every 5 years (US $100 000 each)	20 000
1 new MSc every 4 years (US $60 000 each)	15 000
In-service short courses	9 000
Capital	
2 new vehicles	30 000
Lab equipment	20 000
Farm equipment replacements	12 000
Computers	3 000
Total	289 000

Station Operations

A norm of US $30 per head of cattle (or cattle equivalent) was derived from actual costs in Botswana and Guatemala. The herd or flock sizes are those considered necessary for an effective breeding program.

Utilities

This is also a nominal figure.

Training

The figures shown are based on a turnover time of 15 years for each PhD and MSc and replacing them at a constant rate. Some provision is also made for limited in-service training by bringing in two or three specialists from overseas annually to train a group of staff. This is considered to be more cost effective for an applied research program than sending individuals abroad.

Contract Research

The consultation considered that some funds should be budgeted for contracting research in areas where the research station personnel lacked specific expertise. Contracts might be taken up by the private sector, academic institutions, or overseas consultants.

Capital

Funds are required to replace vehicles, laboratory, and farm equipment on a planned replacement cycle. This is particularly important with respect to transport for substation and on-farm research.

It can be argued that the revenue from station herd sales (US $40 000 to $50 000 yearly) offsets some of the cost of the research program. However, it is normal practice that this revenue reverts to the government and is not usable for research.

TOTAL BUDGET

Table 6 consolidates the personnel and other operating costs in a combined table.

Table 6. Total operating budget (reasonable model).

Category	Cost (thousands of US$)	%
Salaries and wages		
Scientists	197	24
Technical support	120	15
Labour	150	18
Administration	60	7
Materials and supplies		
Research supplies	50	6
Office	10	1
Station operations	15	2
Transport and travel		
Vehicles	30	4
Subsistence (per diems)	15	2
Conferences	5	1
Repairs and maintenance		
Physical plant equipment	15	2
Utilities		
Phone, water, electricity	15	2
Library, documentation, publications		
Books, journals	10	1
Annual report, monographs	5	1
Training		
4–5 year cycle	35	4
In-service short courses	9	1
Contract research	10	1
Capital		
Vehicles	30	4
Laboratory	20	2
Farm equipment	12	1
Computers	3	1
Total	816	100

Table 7. Average total costs per scientist (reasonable model).

	US $	%
Researchers' salaries	9 900	24
Research support staff salaries	13 500	33
Nonsalary research costs	6 000	15
Nonresearch costs	11 500	28
Total	40 800	100

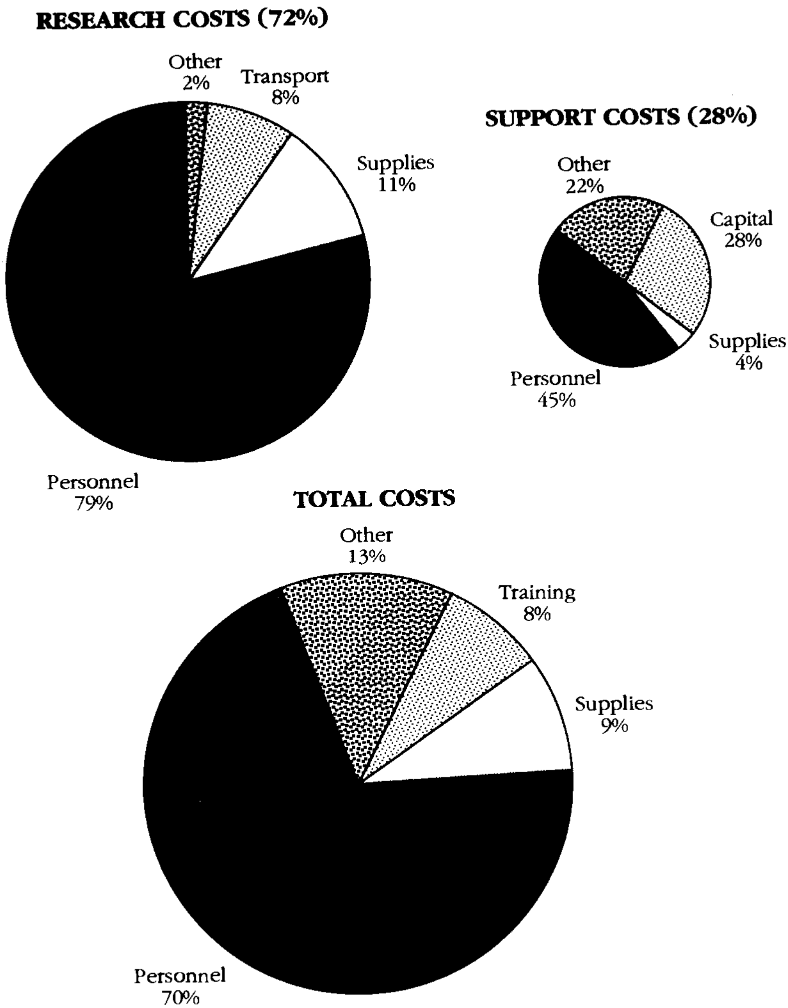

Fig. 3. Relationship between research and support costs.

Research-support costs

The resources allocated in the reasonable model to direct research and support costs are presented in Fig. 3. In this case, salary costs represented the higher limit of 70% of total costs the consultation felt was the maximum level possible.

Average total cost per scientist

At the salary levels given, total operating costs are estimated to be equivalent to just over US $40 000 per professional. The total cost per scientist is similar to the US $42 500 used by Trigo and Pineiro (1984) in their commodity research minimum module, although they used a different cost structure with much higher (US $30 000) salaries for postgraduates and apparently less support staff. However, the figure of US $40 800 does not seem out of line with many of the figures quoted by Oram and Bindlish (1981). It is not readily comparable with the data of Pardey and Roseboom (1989) because the latter are expressed in purchasing power parity.

GDP levels

The derived budget represents an overall research cost of 0.5% of the value contributed by livestock to the GDP. This is well below the 2.0% figure proposed by some agencies but is at the higher end of the spectrum found in middle-income NARS (Judd et al. 1983). This then poses the question as to why, if 0.5% is a "reasonable" figure, so many NARS feel their needs are seriously underfunded. One possible reason, other than the obvious one (that this percentage is too low), is that resources are not being used in an optimal manner, so that some research functions are seriously underfunded in relative terms.

THE MINIMUM MODEL

Having addressed what has been considered a "reasonable" model, the consultation then set out to discuss the extent to which this model could be reduced before a station ceased to be viable. It was decided to maintain the salary levels of the reasonable model, there is considerable evidence to indicate that lower levels seldom result in a sustainable personnel pool. It was also agreed to maintain the restriction that personnel costs not exceed 70% of total costs or this would reduce the productivity of the research team. The discussion then centred on defining the critical mass.

It was agreed that one area where a change could be made was to limit the research program only to cattle, as the economic data in the model country showed that they were much more important than small ruminants.

A second way in which the reasonable model could be curtailed was to eliminate some substations. This obviously needs to be assessed on the basis of development priorities, political imperatives, and existing institutional presence. In the most minimum case reviewed here, one station and no substations would be established.

PERSONNEL

Staffing for the minimum program involved dropping three of the six disciplinary specializations identified in the reasonable model:

- the veterinarian, because much of the research in this area involves herd management and technology transfer; relevant expertise would have to be borrowed or contracted from other sources;

- the management specialist, because his or her primary role was with the small ruminant program, which has to be curtailed; and

- the animal breeder, because it was felt that this was not a sufficiently high priority, and an animal-breeding program was not feasible on a minimal program.

The residual team of senior scientists in nutrition, socioeconomics, and agrostology plus a team leader was considered to be the minimum critical mass for a research program. The reasonable model ratio of one senior scientist to two junior scientists to three technicians (1:2:3) was regarded as still the most appropriate staffing policy and was therefore retained. Because of the absence of substations, the required research force for the minimum model was 4 senior scientists, 8 junior scientists, and 12 technicians (Table 8). Labour numbers could also be halved given the elimination of substations. However, only a limited reduction in administrative staff was feasible, as the office would still need an administrator, an accounts clerk, and a librarian.

Table 8. Research program personnel (minimum model).

Scientists	PhD / MSc	BSc	Diploma
Leader	1	2	3
Nutritionist	1	2	3
Socioeconomist	1	2	3
Agrostologist	1	2	3
Total[a]	4 (7)	8 (13)	12 (20)

[a] Values in parentheses refer to the reasonable model.

BUDGET: PERSONNEL COSTS

Total personnel costs (Table 9) fall from US $527 000 in the reasonable model to US $301 000 in the minimum model, a reduction of 43%.

Table 9. Personnel costs (minimum model).

Category	Number	Unit cost (US $)	Total cost (US $)[a]	
Researchers				(197 000)
PhD	2	15 000	30 000	
MSc	2	12 000	24 000	
BSc	8	8 000	64 000	
Diploma	12	6 000	72 000	(120 000)
Labour	50	1 500	75 000	(150 000)
Administration	3	6 000	18 000	
Secretaries	3	3 000	9 000	
Cleaners/custodians	6	1 500	9 000	
Total			301 000	(527 000)

[a] Values in parentheses refer to the "reasonable model" (see Tables 4 and 5).

Table 10. Nonpersonnel costs (minimum model).

Category	Cost (US $)
Materials and supplies	
Research supplies ($2 500 per professional per year)	30 000
Office supplies ($500 per professional)	6 000
Station operations	—
Transport and travel	
4 vehicles (US $3 000 per year each)	12 000
6 motorcycles (US $200 per year each)	1 200
Per diems (10 scientists × 30 days @ US $25)	7 500
Conferences, etc.	2 500
Repairs and maintenance	
Physical plant, equipment	7 500
Library, documentation, publications	
Books, journals	7 000
Annual report, monographs	3 000
Utilities	
Phone, electricity, water, etc.	7 500
Training	
1 new PhD every 8 years (US $100 000 each)	12 500
1 new MSc every 8 years (US $60 000 each)	7 500
In-service short courses	9 000
Capital	
1 new vehicle	15 000
2 new motorcycles	3 000
Lab equipment	4 000
Computers	3 000
Total	148 200

BUDGET: OTHER COSTS

Nonpersonnel costs have been reduced in the minimum model on a prorated basis (Table 10) except the following:

- Six vehicles have been replaced by motorcycles.
- The cost for station operations and for the research herd have been eliminated. All research costs on the small

Table 11. Total operating budget (minimum model).

Category	Cost (thousands of US$)	%[a]	
Salaries and wages			
Scientists	118.0	26	(24)
Technical support	72.0	16	(15)
Labour	75.0	17	(18)
Administration	36.0	8	(7)
Materials and supplies			
Research supplies	30.0	7	(6)
Office	6.0	1	(1)
Station operations	—	—	(2)
Transport and travel			
Vehicles	13.2	3	(4)
Subsistence (per diems)	7.5	2	(2)
Conferences	2.5	—	(0)
Repairs and maintenance			
Physical plant, equipment	7.5	2	(2)
Utilities			
Phone, water, electricity	7.5	2	(2)
Library, documentation, publications		2	(2)
Books, journals	7.0		
Annual report, monographs	3.0		
Training			
8–15 year cycle	20.0	4	(4)
In-service short courses	9.0	2	(1)
Contract research	10.0	2	(1)
Capital			
Vehicles	18.0	4	(4)
Laboratory	4.0	1	(3)
Computers	3.0	1	(1)
Total	449.2	100	(100)

[a] Values in parentheses refer to the reasonable model.

central station are to be funded from the budget for operational costs of US $2 500 per scientist.

- A slightly higher level of cost per scientist for books and journals is included to compensate for the reduction in size of the research team.

Table 12. Average cost per scientist (minimum model).

Category	US $	%[a]
Researchers' salaries	9 800	26 (24)
Research support staff salaries	12 200	33 (33)
Nonsalary research costs	5 100	14 (15)
Nonresearch costs	10 300	27 (28)
Total	37 400	100 (100)

[a] Values in parentheses refer to the reasonable model.

- Costs for contract collaborative research and short-term training have been maintained at the same level as in the reasonable model. The consultation felt that there would be a relatively greater need for these two activities in a research team reduced to a minimum size.

The net result of these changes is to reduce nonpersonnel costs from US $289 000 to $148 200, a reduction of 49%. This is a larger percentage than the reduction in personnel costs, as it incorporates savings from eliminating station livestock other than those bought for short-term experiments.

The budget for the minimum model is presented in Table 11. The final column of this table shows comparative percentage data from the reasonable model. The two sets of data are broadly compatible. For the minimum models, in relative terms, personnel costs are slightly greater at 67% (or 73% if training is included) and the elimination of substations and the station herd and flock reduces total costs per scientist to US $37 400 (Table 12).

GDP LEVELS

The mandate of the station is confined to the cattle sector whose output was valued at about US $150 million. Thus, the proposed minimum research budget was equivalent to 0.3% of the value of the cattle-sector output.

CONCLUSIONS

This review concluded that the concept of a critical research mass is valid and that it is an important issue to address. Livestock research programs require substantial resources, and there is evidence that adequate resources are not always available or effectively distributed among different research activities.

Within this context, the consultation felt that an effort to quantify the minimum or critical mass of resources needed to provide a reasonable expectation of payoff from research at the station level would be a worthwhile exercise. It also decided that a critical mass of resources must be created at the research-station level, where a research team works together with a given budget. Looking at a national budget may obscure the fact that inadequate resources are available at any one centre.

The absence of reliable information, particularly that relating to the efficiency and effectiveness of livestock research programs, acts as a major constraint when attempting to define standards or norms. There is also a lack of reliable data on the availability and use of resources, and on the relative payoff from different research programs. This makes it difficult to define how programs can be structured and managed when faced with resource constraints.

In such circumstances, the consultation set out to develop an "expert consensus" with respect to defining first a "reasonable" and then a critical mass or "minimum" level of resources required to carry out an effective livestock research program for a given and stated environment. In doing this, particular attention was paid to the process followed in defining the "critical mass," so that the procedures used could be adapted to other situations and others could assess the reliability of the procedures used.

Further research is required to validate these results and to refine the ratios developed in what has been only a first approximation. The models need to be tested under actual station conditions and research undertaken to determine how robust these conclusions are for different country conditions and different livestock environments. Other station costs, which have not been included in this exercise, may be identified from such studies. Service functions for the livestock producers and other nonresearch activities not calculated in this exercise are likely to be found in research station budgets, obscuring the more limited portion that is really available for research. Additional research is also needed to assess the implications of a multistation program in larger countries. Would the ratios used here change significantly as research programs become larger? The levels and combinations of resources used in the models should, therefore, be seen as illustrative and not as rigid standards.

Indeed, the relative ratios of resources used may be more helpful than absolute numbers. These ratios will also be influenced by station size because of economies of scale. Nevertheless, if resources and resource combinations fall below critical levels, the research program will cease to be viable, irrespective of station size.

The findings of the group suggest a number of issues that are noteworthy and vary considerably from existing practices.

STAFFING RATIOS

The critical mass module that was developed had a minimum research team of 4 scientists with postgraduate degrees, 8 scientists with first degrees, and 12 diploma-level staff.

The resulting total of 12 graduate staff is a much larger number then exists in many of the research stations covered in one of the working papers presented at this meeting. Von Hildebrand and Nestel (1991) found that 33 of 116 livestock research stations assessed has 5 scientists or fewer and 46 stations had 10 scientists or fewer.

It was suggested that only a third of the staff need postgraduate qualifications. This is a lower proportion than many developing countries aim to develop. Average levels of scientists with postgraduate degrees range from 30 to 60% of the total number of scientists in different developing regions. However, this lower figure was considered realistic given the applied and adaptive nature of the research required in small research stations.

Each major discipline considered essential in the minimum model would have one senior scientist (postgraduate) working in it, supported by two junior scientists (BSc) and three diploma-level staff. The resulting ratio of 1:2:3 represents a considerably higher proportion of junior staff than prevails in many stations. The most highly educated and the most expensive staff should not be required to spend time doing work that could be done by others just as easily and at less cost. It was suggested that the weaker the infrastructure of administrative and other supporting services, the larger the support staff component should be to compensate for these deficiencies.

A social scientist was identified as one of the core disciplines required in the minimum module. Currently, most livestock research stations are staffed entirely by biological scientists; thus, research findings are not subjected to the type of socioeconomical analysis required to assist in the adoption of results.

PERSONNEL COSTS

One of the most critical guidelines established was the ratio between personnel costs and other costs. It was felt that personnel costs should not exceed 70% of total costs. In practice, personnel cost often exceed this level, with the result that there are insufficient funds for other essential operational requirements such as transport and supplies.

SALARY LEVELS

At the same time, it was agreed that the salaries of scientists must be set at a high enough level to permit them to maintain a reasonable standard of living in their own country. Scientists are the key factor in determining whether or not a program is successful. If they lack resources or incentives, the research programs are unlikely to be effective. Thus, the salaries proposed for scientists in this exercise represented 37% of the total payroll.

The need to constrain total personnel costs below 70% and yet maintain adequate salary levels for the scientific staff is one of the key tradeoffs that must be made in establishing a viable program. This can only by done if the total number of staff employed is limited by the budget available. If the staff to budget ratios are not respected and more staff are employed, then either salary levels will have to be set too low or other operational funds will have to be so constrained that staff are unable to function effectively.

Some norms can be established that demonstrate just how much resources are needed to provide adequate resources per scientist employed. The calculations in this exercise produced an average total cost per scientist of US $44 000. Using the ratio established in this exercise of one senior scientist to two junior scientists, this represents an average annual total cost of $110 000 per senior scientist.

While the individual costs used in these calculations can be adjusted downwards in some countries, establishing this kind of norm is important in assessing the significant cost implications of adding extra staff.

SALARY–TRAINING TRADEOFF

The relationship between salary levels and training costs does not appear to have received much attention in the literature on research resources. It is, however, a matter of considerable importance, especially for governments conducting overseas training on loan programs, as the costs of training are so high. The consultation reviewed the significant relationship that may exist between salary levels and staff-training costs. Low salary levels have been shown to be a factor in increasing the rate of staff turnover. Given the high costs of training, there could even be financial advantages from increasing salary levels and reducing the rate of staff turnover.

Figure 4 shows the annual costs of paying for a PhD at an estimated cost of US $100 000 for external training if the prevailing rate of return on capital is 10%. It shows that salary levels could be increased from US $3 600 to $16 800 per year without increasing the total cost if one could increase the retention rate of staff from an average of 5 to 15 years. Clearly, other factors such as the general working environment or external opportunities influence attrition rates, but low salaries levels were definitely seen as a contributing factor to the high attrition rates that prevail in some countries. This relationship between salary levels and training costs is seen as an issue that deserves closer attention.

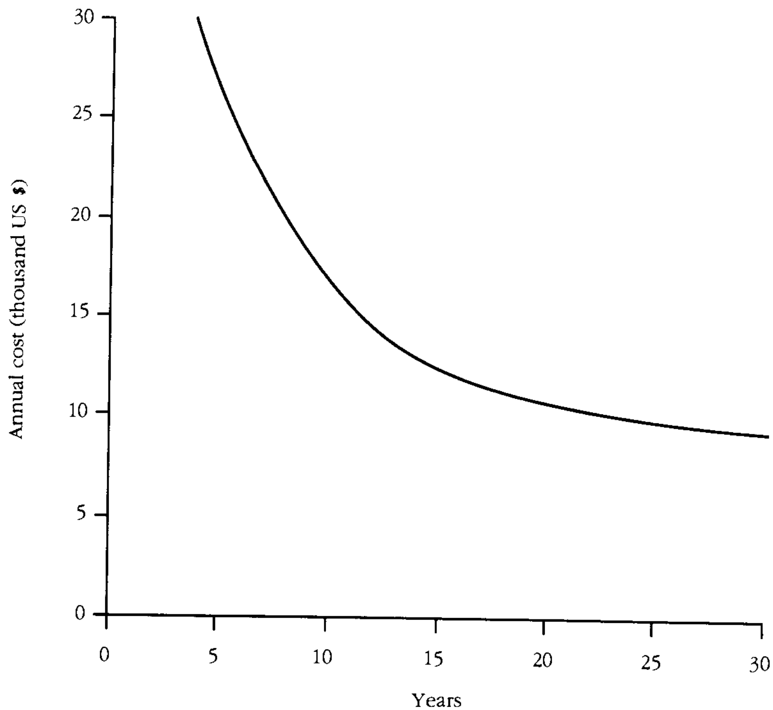

Fig. 4. Annual training cost for PhD (assuming US $100 000 for external PhD training and 10% rate of interest.)

OTHER OPERATING COSTS

The consultation also suggested some minimal levels for the 30% of costs that were not used for personnel. Some of these costs will be very station specific and can only be indicated in nominal terms, such as those for repairs, maintenance, utilities, and mail.

There are, however, some cost items that need to be maintained for a functional program and that are often curtailed when budgets are increasingly used for job creation. The consultation suggested some indicative minimum levels:

- US $2 500 per year per scientist for research supplies, salaries, and materials.
- One vehicle for each two or three scientists and US $3 000 per year per vehicle for operating costs.
- US $500–$700 per year per scientist for books and journals (the higher figure in small stations).
- US $3 000–$5 000 per year for producing annual and scientific reports (without which the station cannot publicize its work).
- US $9 000 per year for in-service local training.
- US $2 500 per year per senior scientist to permit one overseas trip every four years.
- Funds for equipment replacement on a planned cycle.
- US $10 000 per year for collaborative and contract research (essential for a minimum size program).

Most costs will rise almost proportionately as station staff numbers increase. But for the minimum size station, the funds provided for information and for contract and collaborative research will need to be relatively higher to allow for a critical mass of information to be obtained and for contract and collaborative activities needed to fill voids in the expertise of the station personnel. Neglect of some of these relatively inexpensive operational requirements can have a disproportionately negative effect on research productivity.

TOTAL COSTS AND GDP RATIOS

The reasonable station module developed in this exercise produced an annual budget of US $816 000. The minimum station module, below which there was no reasonable expectation that useful research results could be produced, required an annual budget of US $450 000.

The country model used for these calculations had a livestock sector contributing US $160 million annually to GDP. Thus, the reasonable model budget required 0.5% of livestock GDP. The critical mass station module required 0.3% of livestock GDP. Both figures are considerably below the level of GDP frequently suggested as an appropriate allocation for agricultural (livestock) research. However, they are within the range of figures frequently encountered in practice.

If one could calculate the expected payoff from investment in agricultural research, it might be found that a considerably higher percentage of GDP could profitably be invested in livestock research. There is little likelihood, however, that such calculations will prove feasible in the near term and, in any case, constraints on public-sector funding in most countries will likely prevent any significant increases in funding.

An alternative way of looking at resource requirements if this critical mass module held for each research station and there were no significant economies of scale would be a requirement for a livestock GDP of US $44 million for each research station if 1% of livestock GDP was allocated to research. The figure would be doubled to US $88 million if only 0.5% of livestock GDP was available. In Annex 1, Table A2 shows that 20 of the countries covered have a livestock sector smaller than US $88 million; in 38 countries, it is less than US $176 million. The number would be much larger if one included the many smaller countries not included in Table A2.

For those countries with a smaller livestock GDP then, these calculations suggest many countries may already be operating programs below a critical mass of resources necessary for even one station. This probability is increased if one considers non-research costs not included in this module but often found in practice and by the fact that most countries have more than one research station and conduct research programs on more than one species.

BUDGET MANAGEMENT

The deliberations of the consultation suggest that it is also important to look at the way that budgets are allocated to focus on aggregate levels. Resources must be allocated to different research-station functions such as personnel costs, materials, and supplies in a rational manner or research productivity can be severely hampered. Increasing resources will not by itself remove constraints to research effectiveness unless they are allocated appropriately.

An efficient allocation process, however, requires the ability to freely allocate total resources. Unfortunately, in most cases, station managers have very limited influence over the total budget. Employment of personnel may be centred in the headquarters of the Ministry whereas other operating costs are allocated at the station level. Another constraining factor is the policies of external donor agencies who are prepared to fund only certain budget components. If training costs are provided by a donor agency and salary costs covered from another source, there may be little incentive or opportunity for a manager to try to reallocate resources to address inefficiencies. Clearly, as donor agencies are implicated in the way that resources are distributed, they share a responsibility to demonstrate flexibility in contributing to a more rational allocation process.

THE ETHICAL DIMENSION

A better allocation of resources goes beyond questions of efficiency and effectiveness and involves an issue of ethics. It involves the morality of developing a capacity that may be unproductive or of training scientists, particularly from small or poor countries, to a level that their national programs cannot support, or in a skill unlikely to provide benefits that national priorities demand. Most of all, it involves the questionable ethics of educating and employing young scientists who then are placed in conditions where they are unable to contribute and so lose their sense of commitment and spirit of enquiry.

ANNEX 1
LIVESTOCK STATISTICAL TABLES

Table A1. Numbers of livestock (thousands) in selected countries, 1990.

Country	Dual-purpose cattle	Sheep and goats
Southern Africa		
Zimbabwe	6 711	3 421
Angola	3 100	1 260
Zambia	2 861	650
Botswana	2 616	2 394
Namibia	2 072	9 288
Mozambique	1 340	507
Malawi	1 100	1 220
Average	2 833	2 677
Central America		
Honduras	3 514	35
Guatemala	1 800	747
Costa Rica	1 762	5
Nicaragua	1 680	10
Panama	1 502	7
El Salvador	1 193	20
Belize	51	5
Average	1 643	118
Overall average	2 238	1 396

Source: FAO (1990).

Table A2. Contributions of agriculture and livestock to gross domestic product in selected developing countries (thousands of 1988 US $)

Country	Agriculture GDP	Agriculture % of total GDP	Livestock GDP	Livestock % of total GDP	Livestock: agriculture (%)
Afghanistan	1 944	—	809	—	41.61
Algeria	2 123	11	8 665	5.23	47.56
Angola	632	—	201	—	31.80
Argentina	18 221	11	8 665	5.23	47.56
Bangladesh	7 027	46	1 063	6.96	15.13
Benin	554	38	115	7.89	20.76
Bhutan	86	44	22	11.26	25.56
Bolivia	1 071	24	499	11.18	46.59
Botswana	121	3	107	2.65	88.43
Brazil[a]	37 994	8	11 445	7.27	30.14
Burkina Faso	671	37	183	10.09	27.27
Burundi	739	49	42	2.78	5.68
Cambodia	733	—	129	—	17.60
Cameroon	1 419	26	224	4.10	15.79
Central African Republic	363	42	115	13.31	31.68
Chad	554	47	216	18.32	38.99
Chile	2 564	—	1 059	—	41.30
China	165 388	32	43 438	8.40	26.26
Colombia	6 957	19	2 989	8.16	42.96
Congo	155	15	15	1.45	9.68
Costa Rica	907	18	347	6.89	38.26
Cote d'Ivoire[a]	2 522	27	129	3.54	13.12
Cuba	3 045	—	951	—	31.23
Cyprus	269	7	120	3.12	44.61
Dominican Republic	1 207	23	375	7.15	31.07
Egypt	7 241	20	1 920	5.30	26.52
El Salvador	752	14	191	3.56	25.40
Equador	190	15	671	5.27	35.15
Ethiopia	3 243	38	1 299	15.22	40.01
Gabon	86	11	9	1.15	10.47
Gambia	99	27	15	4.09	15.15
Ghana	1 321	49	121	4.49	9.16
Guatemala	1 258	—	331	—	26.31
Guinea	535	—	101	—	18.88
Guinea-Bissau	113	48	25	10.62	22.12
Guyana	202	21	37	3.85	18.32
Haiti	726	31	139	5.94	19.15
Honduras	702	22	190	5.95	27.07
Hong Kong[b]	88	1	63	0.72	71.59

(continued)

Table A2 continued.

	Agriculture		Livestock		
Country	GDP	% of total GDP	GDP	% of total GDP	Livestock: agriculture (%)
India	74 349	29	14 377	5.61	19.34
Indonesia	18 938	26	1 752	2.59	9.97
Iran	7 073	—	2 324	na	32.86
Iraq	1 788	—	620	na	34.68
Jamaica	305	6	115	2.26	37.70
Jordan	341	8	182	4.27	53.37
Kenya	2 202	26	826	9.75	37.51
Korea, DPR	3 994	—	569	—	14.25
Korea, Republic of	5 864	11	1 961	3.68	33.44
Laos People's Democratic Republic	640	—	219	—	34.22
Lebanon	529	—	206	—	38.94
Lesotho	95	16	66	11.12	69.47
Liberia[a]	238	34	20	3.10	9.13
Libya	616	—	306	—	49.68
Madagascar	1 765	41	472	10.96	26.74
Malawi	831	34	98	4.00	11.79
Malaysia	5 407	—	803	—	14.85
Mali	835	49	368	21.60	44.07
Mauritania	188	34	158	28.57	84.04
Mauritius	182	11	24	1.45	13.19
Mexico	16 487	9	7 755	4.23	47.04
Mongolia	754	—	587	—	77.85
Morocco	2 824	17	992	5.97	35.13
Mozambique	796	54	160	10.85	20.10
Myanmar	5 925	—	727	—	12.27
Namibia	300	—	245	—	81.67
Nepal	1 492	52	464	16.17	31.10
Nicaragua	508	—	196	—	33.79
Niger	667	36	314	16.95	47.08
Nigeria	9 780	34	1 749	6.08	17.88
Pakistan	13 771	23	5 738	9.58	41.67
Panama	494	—	220	—	44.53
Papua New Guinea	675	34	50	2.52	7.41
Paraguay	1 960	30	552	8.45	28.16
Peru[a]	2 391	12	986	4.76	39.66
Philippines	6 690	23	1 377	4.73	20.58
Reunion	78	—	19	—	24.36
Rwanda	645	38	70	4.12	10.85

(continued)

Table A2 concluded.

Country	Agriculture GDP	Agriculture % of total GDP	Livestock GDP	Livestock % of total GDP	Livestock: agriculture (%)
Saudia Arabia	1 576	8	853	4.33	54.12
Senegal	817	22	172	4.63	21.05
Sierra Leone[c]	296	39	35	4.55	11.67
Singapore[c]	172	1	168	0.98	97.70
Somalia	709	63	514	45.67	72.45
Sri Lanka	1 757	24	161	2.20	9.16
Sudan	3 261	32	1 901	18.65	58.30
Surinam[c]	96	9	24	2.20	24.49
Swaziland	193	20	47	4.87	24.35
Syria	2 694	38	914	12.89	33.93
Taiwan	3 857	—	1 769	—	45.86
Tanzania	2 837	57	642	12.90	22.62
Thailand	11 208	17	1 887	2.86	16.84
Togo	326	34	37	3.86	11.35
Trinidad and Tobago	105	5	51	2.43	48.57
Tunisia	1 395	12	412	3.54	29.53
Turkey	16 063	16	3 648	3.63	22.71
Uganda	2 840	67	404	9.53	14.23
Uruguay	1 729	9	1 363	7.09	78.83
Venezuela	3 019	6	1 799	3.58	59.59
Vietnam	7 531	—	1 652	—	22.47
Yemen, North	539	24	266	11.84	49.35
Yemen, South[c]	101	13	44	5.66	43.56
Zaire	2 740	31	143	1.62	5.22
Zambia	527	14	169	4.49	32.06
Zimbabwe	1 137	10	260	2.29	22.87

Note: Statistics for 50 developing countries with a population of less than 1 million were not available, and hence have not been included in this table.

Source: USAID (1991).

[a] 1986 values.

[b] 1985 values.

[c] 1987 values.

ANNEX 2
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What is the optimal level and mix of resources needed to conduct an adequate research program?

What are the critical human and financial requirements?

Defining Critical Mass is the first systematic investigation of such crucial research issues. It stems from an Expert Consultation held in Costa Rica in September 1991. Editors Doug Daniels and Barry Nestel present comprehensive guidelines for establishing the minimum resource levels required to successfully undertake animal research programs. Their conclusions suggest that many existing programs may be too small to produce useful results.

The analysis presented in **Defining Critical Mass** could pave the way for major changes in the funding and organization of research.

ISBN 0-88936-649-7