

Monogastric animals are constituting an increasing percentage of global livestock biomass (FAO 1996a,b). This trend is more marked for the continent of Asia as a whole. The global distribution of pigs and poultry is shown in Figures 13 and 14, based on FAO 1994 data. Maps of the livestock production indices for pig meat, all eggs, and hen eggs and chicken meat are shown in Figures 15, 16 and 17. If, however, China is examined separately, non-ruminants are seen to comprise a substantially higher proportion of livestock than elsewhere (36% for China compared with 11% worldwide), but the proportion for China has been static for the last 10–15 years (Slingenbergh and Wint 1997). Care needs to be taken in interpreting Figures 16 and 17 (Livestock production indices for ‘All eggs’ and ‘Hen eggs and chicken meat’) in that poultry biomass comprises broilers and laying stock.

Pigs are most abundant in China, Vietnam and Europe, and are largely absent from the Muslim countries of North Africa and the Middle East (FAO 1996b). Chickens are almost universally distributed, being most abundant in the regions of dense human populations. There are also large numbers of ducks in China. The displacement of ruminants by monogastric livestock is part of a global trend which is particularly biased toward the higher rainfall areas (Slingenbergh and Wint 1997), as shown in Figure 18.

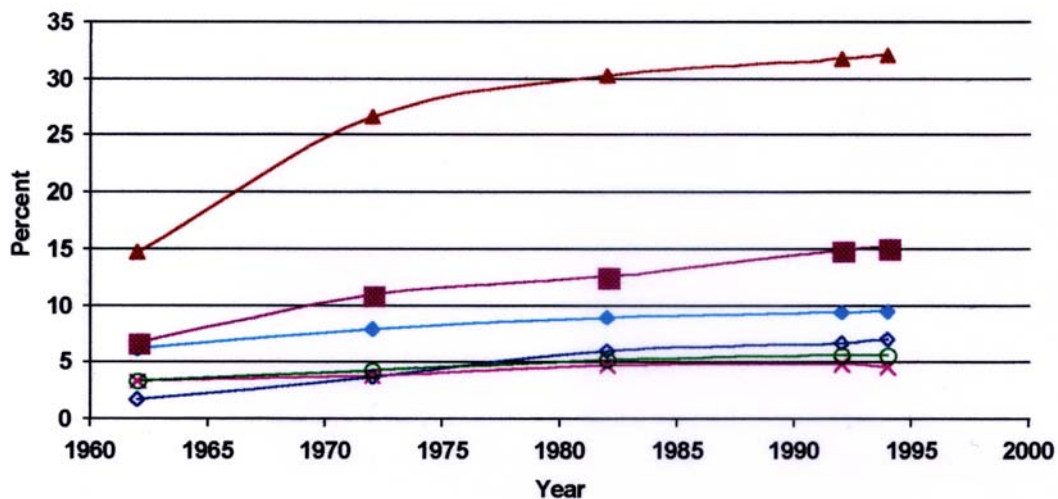


Figure 18. Non-ruminants as a percentage of total biomass by agro-ecological zone (after Slingenbergh and Wint 1997)

It is important to appreciate that the proportion of livestock species biomass within each of the agro-ecological zones within each country does not vary between species. Thus, the proportion of total chickens in a country within the humid zone would equal the proportion of total goats within that zone. Likewise, it is assumed that there are no domesticated livestock of any kind in the desert and arid regions of Australia, because the human population is very low. In large countries such as Australia, where there is a wide diversity of agro-ecosystems, it probably makes inadequate allowance for the agro-climatic constraints on the distribution of the individual livestock species. J. Slingenbergh (pers. comm.) has advised that the derived ruminant distribution for Latin America is known to be rather inaccurate, as is the case for North American pigs and poultry. CIAT is estimating cattle numbers for the different States of Latin America (G. Hyman, pers. comm.), but the data were not available for this study.

While acknowledging these limitations in the data, it needs to be appreciated that they cannot be improved significantly without substantial resources. Furthermore, it is likely that the research prioritising and resource allocation objective for developing this information base will seldom warrant a higher degree of accuracy.

Cattle density data for Africa, ILRI

The International Livestock Research Institute (ILRI) in Nairobi has been collecting country-level cattle census data to create livestock distribution maps, starting with a cattle density layer for a GIS of sub-Saharan Africa (Kruska et al. 1995). The primary purpose of this is to obtain information on the distribution of host populations (such as cattle) to aid animal health studies.

The census figures are usually reported on the basis of administrative boundaries that can vary widely in resolution (province, district, division etc.). ILRI obtained an administrative boundary layer for the continent from FAO, and the best available cattle information was attached. Areas of zero cattle population, such as protected areas and water bodies, were not included, in order to improve density calculations. Because of the variation in the quality of the census figures from country to country, additional attribute fields were added to the density database that include the administrative level of information obtained, as well as the date of the census. Despite the difficulties in assembling these data, ILRI now has cattle distribution for sub-Saharan Africa, generally at the third administrative (sub-district) level (depending on country).

The database is held as an integer type file in ARC/INFO GRID format. The cattle density layer continues to be improved as new information becomes available.

Population data are of more value epidemiologically when spatially related to natural features such as altitude, climate, vegetation, roads and rivers, rather than to administrative boundaries. Demographically, it is best if livestock populations are broken down by species, breed, age and production system. In addition, the understanding of disease spread is enhanced with data on formal and informal livestock markets, and the movement of animals to and from markets.

As previously mentioned, ARC/INFO datasets on Africa for length of growing period (at two levels of aggregation), and cattle density distribution, were made available by ILRI (Figures 3 and 4). A comparison of Figure 4 with the map on global cattle biomass distribution (Figure 7) (FAO 1996b) shows similar patterns of cattle density distribution across Africa.

ILRI is currently starting a new Rockefeller-funded project to put together crop and livestock distribution coverages for eastern and southern Africa (P. Thornton, pers. comm.). The general procedure involves first making a rough estimate of distribution using land use, human population, climate, topography (and whatever else is appropriate), matched by administrative unit to any available census data. Second, NARS (National Agricultural Research Systems) networks are used to find experts in each location to assess the maps and correct them as necessary. These data layers are considered so basic for all sorts of purposes that this activity now has a high priority at ILRI. Given that ILRI has a global mandate, it is interested in obtaining similar crop and livestock coverages for Asia. Work is starting on estimating dairy cattle distributions using simple spatial modelling (e.g. using thresholds of human/cattle populations, agro-ecological zones, etc), simply because for most countries there are no immediately accessible data on dairy cow numbers.

Spreadsheet analyses

The first set of spreadsheets made available in Task 2 is therefore the proportion of livestock, and livestock commodities, within each agro-climatic zone within each country. As explained earlier, only one such matrix (agro-climatic zones × countries) is provided. However, as part of Task 2 this was applied to the major domestic livestock populations and their commodities so that their distribution and significance could be assessed.

Manure is important for agriculture, especially in sandy soil areas for improving fertility and soil structure. It is also important in building (especially for preparing floors), lining baskets and as a supplementary fuel (Scoones 1992). Farmers in the Gambia place a value on manure that equals domestic milk consumption and exceeds that of milk sales (Bennison et al. 1997). Equines, bullocks and cows in one district were important for draught and transport, whereas small ruminants were kept primarily as an investment and for ceremonial purposes.

Manure dispersal (tonnes of dry matter per annum) was estimated using the assumption that intake approximates 2 per cent of liveweight, and the digestibility of the herbage is 50 per cent. It is therefore reasonable to assume that the weight of manure is 1 per cent of liveweight. Given that estimates of the number of cattle, buffalo, sheep and goats had been estimated for the AEZs of each country, and that we had standard liveweights for each species within each continent (see Table 2 above, from FAO 1996b), the calculation is straightforward.

The matrices included in the attached Excel spreadsheet (DW2Matrix.xls) include:

- Percentage of livestock production in each agro-ecological zone, based on FAO (1996a)
- Land areas (km² and percentage)—allocated to agro-ecological zones as per FAO (1996a)
- Cattle numbers, allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Indigenous bovine meat (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Cattle hides (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Dairy cows ('000s), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Cow milk production ('000 t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Cattle manure (t/dry matter/year), allocated to agro-ecological zones using FAO 1996 cattle numbers.
- Buffalo numbers allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Buffalo meat (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Buffalo milk (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Buffalo manure (t/dry matter/year), allocated to agro-ecological zones using FAO 1996 buffalo numbers.

- Sheep numbers, allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Mutton and lamb (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Indigenous sheep and goat meat (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Scoured wool production (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Sheep skins (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Sheep's milk (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Sheep manure (t/dry matter/year), allocated to agro-ecological zones using FAO 1996 sheep numbers.
- Goat skins (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Goat's milk (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Goat manure (t/dry matter/year). Allocated to agro-ecological zones using FAO 1996 goat numbers.

Table 4. Commodity total for each of the agro-climatic zones

Commodity	Desert	Arid	Semi-arid	Dry Sub-humid	Moist Sub-humid	Humid
Ind. Bovine meat (kt)	1,913	1,146	4,238	9,410	24,233	16,623
Fresh cattle hides (kt)	256	150	625	1,437	2,835	1,943
Cows milk (kt)	11,982	8,475	39,467	87,897	223,138	95,898
Cattle manure (kt dry matter)	47,445	29,849	141,040	326,490	648,590	499,534
Buffalo meat (kt)	437	104	348	796	665	354
Buffalo milk (kt)	9,407	2,837	9,072	18,660	9,856	2,042
Buffalo manure (kt dry matter)	20,573	6,321	28,229	72,846	62,608	31,535
Mutton and lamb (kt)	595	302	1,036	1,281	1,887	2,178
Indigenous sheep and goat meat (kt)	888	446	1,528	2,084	2,859	3,053
Scoured wool (kt)	60	56	159	228	390	717
Sheep skins (kt)	116	65	194	240	843	428
Sheep milk (kt)	761	357	1,441	1,734	2,714	700
Sheep manure (kt dry matter)	9,131	5,040	19,023	24,348	38,148	47,036
Goat skins (kt)	92	31	97	167	203	166
Goat milk (kt)	1,138	489	1,666	2,416	3,695	740
Goat meat (kt)	431	141	476	777	939	793
Goat manure (kt dry matter)	5,845	2,269	9,602	15,695	19,747	13,481
Indigenous pig meat (kt)	1,037	503	2,812	13,489	39,236	27,822
All poultry meat (kt)	2,329	758	3,099	8,085	24,974	19,098
All poultry eggs (kt)	1,335	480	2,683	8,523	18,760	15,390
Hen eggs (kt)	1,277	467	2,577	7,832	17,387	13,531
Land area ('000 km ²)	26,648	10,156	26,197	27,625	23,462	21,104

- Pig numbers, allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Indigenous pig meat (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Chicken numbers, allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- All poultry meat (t), for all classes of poultry, allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Poultry eggs (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.
- Hens' eggs (t), allocated to agro-ecological zones as per FAO (1996b) using FAO 1996 data.

Totals produced for the different commodities in each of the agro-ecological zones are shown in Table 4.

TASKS 3 AND 4. TECHNICAL SPILLOVERS BETWEEN AGRO-CLIMATIC ZONES

The terms of reference for this component of the study were:

Task 3. Semi-quantitatively estimate the potential for technical spillovers between agro-climatic zones assuming a preharvest research project;

Task 4. Semi-quantitatively estimate the potential for technical spillovers between agro-climatic zones assuming a postharvest research project.

Given that Tasks 5 and 6 are devoted to research capacity and adoption, the capacity for technical spillover in this section is confined to the effects of physical and biological differences between the agro-climatic/agro-ecological zones. The underlying question presupposes that ACIAR funds a research activity in an agro-climatic zone, and develops a technology that is most suited to that agro-climatic zone. What is sought is an appreciation of how that technology would perform against the best available technology in other agro-climatic zones.

The chosen approach therefore involved first considering the constraints to technology spillovers between agro-climatic zones, from the consideration of the livestock commodity and the technology being evaluated. It was appreciated that there are also a host of social, cultural, educational, financial and even political factors (e.g. prohibition of the movement of livestock across national boundaries) that can limit adoption, and which are more relevant to Task 6. Political boundaries rarely coincide with broad ecological zones.

In achieving this task it was recognised that:

- the estimates are to be semi-quantitative estimates of average spillovers of research impacts between zones;
- the estimates are to be [weighted] averages over all possible research projects;
- the estimates are to be specific to a commodity; and
- the matrix of spillover indices is symmetric.

Estimates of technical spillovers for preharvest research projects

There is a wide range of ruminant production systems. The simplest involve livestock grazing native grassland, either within a fixed property boundary or, at the other extreme, as part of a nomadic lifestyle. More intensive systems involve subdivided properties with the livestock grazing improved pastures and/or fodder crops, the most intensive systems being typified by the livestock being housed and fed ensiled pasture and crops and/or feed concentrates.

Consider first an animal health technology, such as a new vaccine. This could apply across the whole range of agro-ecosystems, so that the spillover coefficients will be high. Physical constraints to its use might include the range of the vector (e.g. bioclimatic limits of the tsetse fly or the cattle tick), the density of livestock (disease spread limited at very low stocking rates), the natural level of resistance to the vector or the disease (e.g. cattle tick), soil and pasture characteristics (e.g. persistent moisture for footrot in sheep), presence of and access to alternative hosts (e.g. tuberculosis in cattle), availability of fencing (e.g. to help control venereal diseases), the availability of veterinary services, and the level of nutrition and hence vulnerability to disease of the animals themselves. It is also noted that many animals move around on transhumance in the arid, semi-arid and sub-humid areas of Africa. This presents problems to animal health control, and in ensuring that grazing pressure does not exceed both the short- and long-term carrying capacity of the land.

Technologies applying to the pasture plants will often have different geographic ranges to the technologies that apply to the livestock. In southern Australia, a quasi-Mediterranean (winter rainfall) region dominated by exotic C3 plants, the availability of pasture dry matter is more important than pasture quality over most of the year. By comparison, in the sub-tropical north where rainfall is dominated by the summer monsoon, the feed quality of the dominant C4 plants will have a greater influence on production. C3 plants include most of the temperate and Mediterranean species, and most trees and shrubs in which the first products of photosynthesis are made up of C3 compounds. They have an optimal functioning temperature of around 15–20°C. The C4 species include tropical species, particularly grasses such as maize, sorghum, and sugarcane, but not rice. The optimum functional temperature of C4 species is around 25–30°C.

Rangeland maintenance requires an appreciation of the sensitivity of rangeland ecosystems, which are often being exposed to pressure from livestock species that are markedly different from those under which they evolved. Technologies developed in these areas may have limited applicability elsewhere. Likewise, technologies developed for improved pastures and intensive grazing systems will often have limited relevance to rangeland systems.

There also needs to be an appreciation of biophysical constraints that limit technological uptake within the zone in which it is developed. In more intensive grazing systems, improving the productivity on one part of a farm often limits the production on another part of the farm. Likewise, improving survival of, say, young stock during one part of the year may have deleterious effects on the breeding livestock which limit their performance in subsequent seasons (Bowman et al. 1989). A major impact of an aggressive grass within a sward may be to smother a valuable legume. There are therefore many factors, including biological feedbacks, that can contribute to why the value of a technology that appears considerable in the narrow confines of a field experiment, is not achieved in practice. It should also be noted that many ‘technical experts’ have been trained in environments that are so dissimilar to their countries

that the technologies they, and ‘visiting experts’, attempt to introduce are at best inappropriate, and often counter-productive (Morley and White 1985; Scoones 1992).

For the above reasons it was decided, after consulting with ACIAR, to apply the following dichotomies. Instead of providing matrices of coefficients representing technical spillovers for the different commodities, these were split into ruminants versus non-ruminants. The coefficients were assumed to be relatively similar between livestock species within these groupings. However, different matrices were applied in Task 3 to differentiate between animal health, animal production and agronomic (including soil amelioration) technologies. With non-ruminants the agronomic technologies applied solely to the fodder on offer, and were considered part of non-ruminant production. There were therefore five matrices developed to fulfil the requirements of Task 3. The coefficients themselves are in fact best estimates made after systematically taking into account the major factors that would influence the pre- and postharvest transfer of different technologies in these areas, as indicated below, and discussing them with others.

The first matrix is for animal health services applied to ruminants (Table 5). It was assumed that the effectiveness of most vaccines and medicines would be relatively independent of the agro-climatic zone in which they were applied, although the epidemiology of different diseases would certainly be affected by climate and other environmental factors. Herds and flocks in the more-arid zones would be less exposed to disease, which would in part compensate for the reduced lack of access to animal health services. As with other matrices, it is important to be conscious of the limits to vector and host ranges, which can have an overriding influence on the relevance and value of specific technologies.

Table 5. Technical preharvest spillovers: estimates for ruminant health

Zones	Desert	Arid	Semi-arid	Dry Sub-humid	Moist Sub-humid	Humid
Desert	1.00	0.90	0.80	0.70	0.60	0.50
Arid	0.90	1.00	0.90	0.80	0.70	0.60
Semi-arid	0.80	0.90	1.00	0.90	0.80	0.70
Dry Sub-humid	0.70	0.80	0.90	1.00	0.90	0.80
Moist Sub-humid	0.60	0.70	0.80	0.90	1.00	0.90
Humid	0.50	0.60	0.70	0.80	0.90	1.00

The second matrix is for animal production technologies applied to ruminants (Table 6). It was assumed that different breeds and production systems of sheep, cattle and goats would dominate different areas. Although there are many commonalities between the rumens of say cattle in tropical and temperate areas, there are also significant differences in feedstuffs and rumen flora. The impact of, say, stocking rate, grazing management, date of parturition and drought strategies on herbage quantity and quality and sward ecology will vary significantly between grassland systems in arid and humid environments.

The third matrix is for agronomic services applied to ruminants (Table 7). It was assumed that the ecological boundaries of different rangeland and grassland ecozones would limit the spillover of many agronomic (and soil) technologies across zone boundaries. Plant species that thrive in one environment may not persist in others. Drought tolerance and plant persistence under either continuous or intermittent grazing can greatly influence grassland productivity, plant cover and soil stability, particularly in adverse seasons. The ‘benefits’ of introduced

plants may only be realised given sustained rainfall or irrigation water, fertilizer inputs and pest control. Legume content of pastures may be critical to productivity, sustainability and financial viability. As with other matrices, it is important to be conscious that there is a wide range of technologies with different geographical ranges, which can have an over-riding influence on the relevance and value of specific technologies.

Table 6. Technical preharvest spillovers: estimates for ruminant production

Zones	Desert	Arid	Semi-arid	Dry Sub-humid	Moist Sub-humid	Humid
Desert	1.00	0.85	0.70	0.40	0.30	0.20
Arid	0.85	1.00	0.85	0.50	0.40	0.30
Semi-arid	0.70	0.85	1.00	0.75	0.50	0.40
Dry Sub-humid	0.40	0.50	0.75	1.00	0.80	0.70
Moist Sub-humid	0.30	0.40	0.50	0.80	1.00	0.85
Humid	0.20	0.30	0.40	0.70	0.85	1.00

Table 7. Technical preharvest spillovers: estimates for agronomy in ruminant systems

Zones	Desert	Arid	Semi-arid	Dry Sub-humid	Moist Sub-humid	Humid
Desert	1.00	0.75	0.60	0.20	0.10	0.05
Arid	0.75	1.00	0.80	0.30	0.20	0.10
Semi-arid	0.60	0.80	1.00	0.60	0.30	0.20
Dry Sub-humid	0.20	0.30	0.60	1.00	0.80	0.60
Moist Sub-humid	0.10	0.20	0.30	0.80	1.00	0.80
Humid	0.05	0.10	0.20	0.60	0.80	1.00

Pigs and poultry tend to be concentrated in the crop-growing areas, though there may be environmental constraints associated with the high water demands and effluent disposal requirements of intensively-housed livestock. As became apparent in Task 2, the density of non-ruminants and ruminants is commonly low in the more arid areas.

Technical spillovers were considered to be similar for pigs and poultry; agronomic technologies would be relevant only as far as they affect the dominant feedstuff. The distinction was made between non-ruminant health and production (Tables 8 and 9).

Table 8. Technical preharvest spillovers: estimates for non-ruminant health

Zones	Desert	Arid	Semi-arid	Dry Sub-humid	Moist Sub-humid	Humid
Desert	1.00	0.95	0.90	0.85	0.80	0.70
Arid	0.95	1.00	0.95	0.90	0.85	0.80
Semi-arid	0.95	1.00	1.00	0.90	0.85	0.80
Dry Sub-humid	0.85	0.90	0.95	1.00	0.95	0.90
Moist Sub-humid	0.80	0.85	0.90	0.95	1.00	0.95
Humid	0.70	0.80	0.85	0.90	0.95	1.00

Estimates of technical spillovers for postharvest projects

In estimating the potential for technical spillovers between agro-climatic zones assuming a postharvest research project (Task 4), emphasis needs to be given to the commodity, rather

than the zone in which it was produced. Constraining factors would include the local transport and processing infrastructure, and access to resources including expertise. Obviously these are likely to be less developed and not as abundant in the more arid and remote areas. An exception to this is in the arid areas of most of the Middle East, where transport and access to resources is in fact reported to be very good (W. Wint, pers. comm.). Nevertheless, one would expect fewer major constraints to technical spillovers between agro-climatic zones with postharvest projects. Coefficients will therefore often be higher than for preharvest projects on livestock production and agronomy.

Table 9. Technical pre-harvest spillovers: estimates for non-ruminant production

Zones	Desert	Arid	Semi-arid	Dry Sub-humid	Moist Sub-humid	Humid
Desert	1.00	0.90	0.80	0.60	0.50	0.40
Arid	0.90	1.00	0.90	0.70	0.60	0.50
Semi-arid	0.80	0.90	1.00	0.80	0.70	0.60
Dry Sub-humid	0.60	0.70	0.80	1.00	0.90	0.80
Moist Sub-humid	0.50	0.60	0.70	0.90	1.00	0.90
Humid	0.40	0.50	0.60	0.80	0.90	1.00

It was decided that the most appropriate dichotomy would be between meat, milk, fibre and egg commodities.

Meat processing may be undertaken on site by the producer, or by appropriately trained workers in an abattoir. Meat is a perishable product, although it can be salted and dried. Lack of affordable refrigerated transport can be a problem in remote areas, and lack of appropriate veterinary controls can lead to meat being unsuitable for either domestic consumption or export. Transport of live animals can lead to losses through excessive bruising. Estimates for postharvest spillovers associated with meat processing are shown in Table 10.

Table 10. Technical post-harvest spillovers: estimates for meat processing

Zones	Desert	Arid	Semi-arid	Dry Sub-humid	Moist Sub-humid	Humid
Desert	1.00	0.90	0.80	0.70	0.60	0.50
Arid	0.90	1.00	0.90	0.80	0.70	0.60
Semi-arid	0.80	0.90	1.00	0.90	0.80	0.70
Dry Sub-humid	0.70	0.80	0.90	1.00	0.90	0.80
Moist Sub-humid	0.60	0.70	0.80	0.90	1.00	0.90
Humid	0.50	0.60	0.70	0.80	0.90	1.00

Most milk processing takes place near where the milk is produced, so that processing plants are concentrated in the higher rainfall and irrigated areas. Transport of perishable milk and milk products can be a major constraint, particularly in hotter and more remote areas and where affordable refrigerated transport is not readily available (Table 11).

Fibre processing depends primarily on having skilled workers. These can range from, say, Bedouin women spinning yarn and weaving cloth in tents in remote arid areas, to urban workers operating modern equipment in large factories. The effects of agro-climatic zones relate primarily to transport difficulties, and to vegetable contamination. The coefficients for spillover between regions of postharvest technologies were therefore rated highly (Table 12).

Table 11. Technical postharvest spillovers: estimates for milk processing

Zones	Desert	Arid	Semi-arid	Dry Sub-humid	Moist Sub-humid	Humid
Desert	1.00	0.90	0.80	0.60	0.50	0.40
Arid	0.90	1.00	0.90	0.70	0.60	0.50
Semi-arid	0.80	0.90	1.00	0.80	0.70	0.60
Dry Sub-humid	0.60	0.70	0.80	1.00	0.90	0.80
Moist Sub-humid	0.50	0.60	0.70	0.90	1.00	0.90
Humid	0.40	0.50	0.60	0.80	0.90	1.00

Table 12. Technical postharvest spillovers: estimates for fibre processing

Zones	Desert	Arid	Semi-arid	Dry Sub-humid	Moist Sub-humid	Humid
Desert	1.00	0.95	0.90	0.85	0.80	0.70
Arid	0.95	1.00	0.95	0.90	0.85	0.75
Semi-arid	0.90	0.95	1.00	0.95	0.90	0.80
Dry Sub-humid	0.85	0.90	0.95	1.00	0.95	0.90
Moist Sub-humid	0.80	0.85	0.90	0.95	1.00	0.95
Humid	0.70	0.75	0.80	0.90	0.95	1.00

Most eggs are probably used as is, at least in developing countries, rather than as an ingredient in food processing. They are also less likely than most other food products to quickly perish. Rough handling during grading and transport can cause losses through breakage. The coefficients for spillover between regions of postharvest technologies were therefore rated highly (Table 13).

Table 13. Technical postharvest spillovers: estimates for egg handling and processing

Zones	Desert	Arid	Semi-arid	Dry Sub-humid	Moist Sub-humid	Humid
Desert	1.00	0.95	0.90	0.80	0.70	0.60
Arid	0.95	1.00	0.95	0.90	0.80	0.70
Semi-arid	0.90	0.95	1.00	0.95	0.90	0.80
Dry Sub-humid	0.80	0.90	0.95	1.00	0.95	0.90
Moist Sub-humid	0.70	0.80	0.90	0.95	1.00	0.95
Humid	0.60	0.70	0.80	0.90	0.95	1.00

TASKS 5 AND 6. CAPACITY OF COUNTRIES TO UNDERTAKE RESEARCH AND USE RESEARCH RESULTS

The terms of reference for this component of the study were:

Task 5 Semiquantitative expert assessments of the capacity of different countries to undertake basic research, and adaptive research in the agricultural sector;

Task 6. Semiquantitative expert assessments of the ability of producers in different countries to adopt and apply research results.

Research capacity

A country's research capacity may be measured in terms of its local and imported skills base, research resources, and the quantity, quality and relevance of its research products. Research resources include the research infrastructure in terms of relevant tertiary education and research institutions, and essential laboratory, field and computing resources. The skills base is of course the most important, and can in part be measured in terms of numbers of graduates and postgraduates, and years of experience on relevant topics. Just as important, but more difficult to measure, is whether they have the appropriate skills, vision, motivation and appreciation of the major issues that need to be addressed. Research output is often measured in terms of the number and quality of scientific publications, though of more immediate relevance is identifying discernible improvements in agricultural and environmental policy, and the management of agricultural production systems. An appropriate balance also needs to be struck between strategic and applied research.

Many low-cost technologies and technologies adapted for local use contain a large amount of research-based knowledge (Thulstrup 1994). This makes very demanding not only the development of competitive technology, but also technology import and modification. Local human capability at a high level is therefore required, both with respect to knowledge of the relevant field, and in terms of analytical and decision-making skills.

Research capacity for individual countries was estimated after summarising information contained in the databases described below. The data are summarised in Appendix 1. The estimates of direct research relativity (where the research is undertaken locally) and adaptive research relativity (the ability to interpret and make use of overseas research) is set out in Table 14. It is acknowledged that these are subjective estimates, albeit based as systematically as possible on the quantitative information contained in the databases (Appendix 1). The number of data available on different countries differed considerably. Thus, using information elaborated on below, the research capacity of most African countries was initially ranked on the basis of researchers per million farmers, and research expenditure as a percentage of agricultural gross domestic product (GDP). A crude ranking was also made of groups of countries in terms of numbers of agricultural graduates, veterinarians and auxiliary health personnel, and the size and number of relevant universities and research institutions, relative to the size of the local livestock industries. The commitment of countries to secondary and tertiary education was also determined, from UNESCO data. Finally, other factors including personal knowledge about research standards and livestock industries in different countries were taken into account.

The International Service for National Agricultural Research (ISNAR) is developing a global database on national agricultural research systems. Pardey and Roseboom (1989) published details of graduate numbers and agricultural research expenditure in many countries, with some information on the mainly government and academic institutions in which they worked. Since then ISNAR, with support from the Government of Italy and the Special Program for African Agricultural Research (SPAAR), has published a series of Statistical Briefs (Beintema et al. 1994a,b, 1995a,b,c,d, 1996; Mazzucato 1994a,b; Mazzucato and Ly 1993, 1994; Roseboom and Pardey 1993a,b,c,d, 1994a,b, 1995; Roseboom et al. 1993, 1994, 1995a,b) containing considerable details on agricultural research resources in most countries of Africa, and Colombia in South America. Measures of research capacity include researchers per million farmers, and research expenditure as a percentage of agricultural GDP. IFPRI, of which Dr Pardey is a member, plans to complete the main phase of work on research evaluation and priority setting in Latin America in 1998, and by 2001 to complete the main phase of similar work in Asia < <http://www.cgiar.org/ifpri/themes/grp1.htm> >.

The Commonwealth Agricultural Bureau (Vernon 1989) has published details on staff in government departments, research institutes and universities in 32 countries of the British Commonwealth. This provides details on individual researchers, including their qualifications, position and areas of specialisation. It is therefore possible to estimate the emphasis given to different livestock species. It is also reasonable to refer to the livestock numbers and commodities produced in the different countries, in that the available expertise is likely to be allocated to servicing those industries that are of most value to the national economy.

The numbers of veterinarians and animal health auxiliary personnel are published annually by the FAO, in collaboration with the Office International des Epizooties and the World Health Organization (FAO/OIE/WHO 1997). This also identifies, inter alia, the numbers of veterinarians working in laboratories, universities and training institutions.

The UNESCO database on educational indicators was also accessed, special attention being given to the proportion of the population that is undertaking tertiary (Third Level) studies, and public expenditure on education as a percentage of gross national product (GNP), and as a percentage of total government expenditure. This provides a view of the government's commitment to education, a necessary precursor for adequate research and extension services, and whether or not there is an adequate pool of young people who can be provided with appropriate tertiary training.

Research adoption

Understanding the full value of livestock within agropastoral systems requires a detailed study of outputs and functions under peasant farming conditions. Recent studies of other livestock systems have demonstrated the productive value of traditional pastoral systems (de Ridder and Wagenaar 1986; Behnke 1985).

Scoones (1992) found that returns to land in the communal area livestock system in southern Zimbabwe were considerably higher than in conventional beef ranching systems, provided the full value of livestock products and services was accounted for. This finding of higher returns per animal and per unit area for communal area livestock production runs counter to the common interpretation of communal area production systems. Effective economic evaluations therefore require detailed knowledge of the livestock system.

Cattlemen in north Queensland choose to maintain a medium of adoption in harmony with their environment, rather than adopt innovations which scientists implicitly have perceived as desirable, profitable and suitable (Frank 1995, 1997). If they have a sufficient level of managerial skill and resources, and they experience a declining return per production unit, they adopt innovations which offer a means of arresting that decline. The only common dimension for all innovations was ‘social acceptance’, associated with environmental stability.

Constraints to the adoption and application of research are therefore often difficult to identify, let alone quantify. It is worth having a checklist to help identify which may be important with respect to a particular technology.

Scientific and technical constraints

Is the research relevant to meeting the needs of local producers? Many researchers understandably undertake research within their areas of expertise, but these may not be relevant. This problem is often exacerbated when researchers are trained in countries with, say, subsidised agricultural systems favouring expenditure on high-cost inputs which may be quite irrelevant to the agriculture in their home countries.

Are necessary inputs available?

Is the product acceptable to farmers, processors and consumers?

Are there any biological feedbacks that could diminish the anticipated benefits from the research? Will productivity be reduced in another part of the paddock or farm, or in the subsequent season?

Is the research properly conducted and supervised—is the design appropriate, and will the findings most likely be due to the treatments applied, rather than to chance or poor technique (e.g. Morley and Spedding 1968)?

Will a climatic shift or other environmental change negate or enhance the benefits of the proposed change to local agricultural systems? Do several management inputs have to be changed simultaneously in order for the productivity, sustainability and financial viability of an agricultural system to be significantly improved? Are models required to estimate the benefits, and are suitable validated models available?

Socioeconomic and cultural constraints

- Is there adequate economic incentive for a new technology to be adopted. Is it profitable? What are the alternatives?
- Will critical inputs, such as preventative measures, be maintained?
- Is there a high level of risk associated with applying the technology?
- Will substantial debt be incurred in adopting the technology?
- Do farmers have access to credit at reasonable rates?
- What is the opportunity cost of not adopting the technology?
- Are there any cultural or religious constraints (e.g. no pigs in Muslim countries)?
- Is there any health or safety risk or discomfort associated with applying the technology?
- Is there a regional ‘technology champion’, and is he/she held in high respect?

- Is there any reason why farmers might be ridiculed or ostracised by the local community for being innovative?
- Do farmers have adequate skills, and/or access to relevant information and training?
- Is the local transport, processing and marketing infrastructure adequate, or can it be made so?

Coefficients representing extension capacity were prepared taking account of the above, available expertise (Appendix 1) and the relative emphasis on different domestic species in different countries (Table 14). In an independent study, Winrock International concluded that research productivity ratios in Sub-Saharan Africa, when measured in output per unit of land, labour, and fertilizer, are the lowest of all regions of the world (Anon. 1992). They also concluded that extension agencies are not effective in taking new knowledge to farmers because of deficiencies in the structure of extension systems and in functions of extension agents, lack of cost-effective means of technology transfer, and weak linkages with research institutions.

Table 14. Estimates of capacity to undertake basic research and adaptive research, and extension into agricultural practice

Country/region	Direct research relativity	Adaptive research relativity	Ceiling level of adoption			
			Cattle	Sheep, goats	Pigs	Poultry
Bangladesh	0.30	0.35	0.50	0.40	0.00	0.40
Bhutan	0.05	0.20	0.30	0.20	0.30	0.30
India	0.75	0.80	0.70	0.50	0.60	0.60
Nepal	0.30	0.40	0.40	0.40	0.40	0.40
Pakistan	0.40	0.50	0.50	0.40	0.00	0.40
Sri Lanka	0.45	0.60	0.50	0.40	0.30	0.40
Myanmar	0.20	0.30	0.30	0.30	0.30	0.30
Indonesia	0.45	0.55	0.50	0.50	0.50	0.50
Kampuchea	0.20	0.30	0.30	0.10	0.20	0.30
Laos, PDR	0.20	0.30	0.50	0.20	0.50	0.50
Philippines	0.30	0.40	0.50	0.40	0.50	0.50
Vietnam	0.25	0.35	0.40	0.40	0.30	0.40
Malaysia	0.30	0.40	0.50	0.20	0.50	0.60
Thailand	0.30	0.40	0.50	0.40	0.50	0.50
China PDR	0.60	0.75	0.70	0.70	0.70	0.70
Mongolia	0.35	0.45	0.50	0.60	0.30	0.30
Papua New Guinea	0.30	0.40	0.30	0.20	0.40	0.30
Fiji	0.20	0.30	0.30	0.40	0.30	0.40
Samoa, Western	0.10	0.20	0.30	0.10	0.30	0.30
Solomon Is.	0.10	0.20	0.30	0.10	0.30	0.30
Tonga	0.10	0.20	0.30	0.10	0.30	0.30
Vanuatu	0.10	0.20	0.30	0.10	0.30	0.30
South Pacific–Other	0.10	0.20	0.30	0.10	0.30	0.30
Angola	0.05	0.20	0.30	0.30	0.30	0.30
Botswana	0.25	0.50	0.40	0.50	0.40	0.40
Lesotho	0.20	0.40	0.40	0.40	0.30	0.40
Malawi	0.30	0.45	0.40	0.50	0.40	0.40
Namibia	0.50	0.65	0.50	0.50	0.40	0.40
Mozambique	0.20	0.35	0.40	0.40	0.30	0.40

Table 14. Estimates of capacity to undertake basic research and adaptive research, and extension into agricultural practice

Country/region	Direct research relativity	Adaptive research relativity	Ceiling level of adoption			
			Cattle	Sheep, goats	Pigs	Poultry
Swaziland	0.25	0.35	0.40	0.50	0.40	0.50
South Africa	0.80	0.85	0.75	0.75	0.75	0.75
Tanzania	0.40	0.50	0.60	0.40	0.40	0.40
Zambia	0.50	0.65	0.60	0.50	0.50	0.50
Zimbabwe	0.60	0.70	0.70	0.60	0.50	0.50
Kenya	0.60	0.70	0.70	0.50	0.50	0.50
Mauritius	0.15	0.30	0.30	0.30	0.20	0.30
East Africa—other	0.20	0.30	0.30	0.30	0.20	0.30
African Is (Indian Ocean)	0.25	0.35	0.30	0.30	0.30	0.30
Central Africa	0.15	0.30	0.30	0.30	0.30	0.30
West Africa	0.25	0.40	0.30	0.30	0.00	0.30
West Asia–North Africa	0.30	0.50	0.60	0.60	0.00	0.40
Latin America	0.50	0.60	0.60	0.60	0.60	0.60
Asia—Developed	0.75	0.80	0.80	0.80	0.80	0.80
Australia	0.90	0.90	0.90	0.90	0.90	0.90
Canada	0.85	0.85	0.90	0.80	0.90	0.90
USA	0.95	0.95	0.90	0.80	0.90	0.90
USSR	0.50	0.65	0.60	0.60	0.60	0.60
Japan	0.75	0.80	0.80	0.80	0.80	0.80
Developed 1–2	0.60	0.70	0.70	0.75	0.60	0.70
Developed 3–4	0.75	0.85	0.85	0.85	0.80	0.80

FAO regions

Western Africa	Central Africa	Eastern Africa
Benin	Angola	British Indian Ocean Territories
Burkina Faso	Cameroon	Burundi
Cape Verde	Central African Republic	Comoros
Côte d'Ivoire	Chad	Djibouti
Gambia	Congo	Eritrea
Ghana	Equatorial Guinea	Ethiopia
Guinea	Gabon	Kenya
Guinea-Bissau	Sao Tome and Principe	Madagascar
Liberia		Malawi
Mali		Mauritius
Mauritania		Mozambique
Niger		Reunion
Nigeria		Rwanda
Senegal		Seychelles
Sierra Leone		Somalia
St Helena		Tanzania
Togo		Uganda
		Zambia
		Zimbabwe

Near East/North Africa	Latin America	USSR, former area of
Afghanistan	Argentina	Armenia
Algeria	Belize	Azerbaijan
Bahrain	Bolivia	Belarus
Cyprus	Brazil	Estonia
Egypt	Chile	Georgia
Gaza Strip	Colombia	Kazakhstan
Iran	Costa Rica	Kyrgyzstan
Iraq	Ecuador	Latvia
Jordan	El Salvador	Lithuania
Kuwait	Falkland Islands	Moldova Republic
Near East/North Africa	Latin America	USSR, former area of
Lebanon	French Guiana	Russian Federation
Libya	Guatemala	Tajikistan
Morocco	Guyana	Turkmenistan
Oman	Honduras	USSR
Qatar	Mexico	Ukraine
Saudi Arabia	Nicaragua	Uzbekistan
Syria	Panama	
Tunisia	Paraguay	
Turkey	Peru	
United Arab Emirates	South Georgia	
Yemen	Suriname	
	Uruguay	
	Venezuela	
Asia—Developed	Developed 1–2	Developed 3–4
Bahrain	Albania	Belgium–Luxemburg
Brunei	Cyprus	Denmark
Gaza Strip	Greece	France
Hong Kong	Italy	Germany
Israel	Portugal	Netherlands
Korea, DPR	South Africa	New Zealand
Korea, Rep	Spain	Poland
Kuwait	Yugoslavia	United Kingdom
Macao	Austria	Faeroe Island
Oman	Bulgaria	Falkland Islands
Qatar	Czechoslovakia	Finland
Saudi Arabia	Hungary	Greenland
Singapore	Romania	Iceland
Taiwan	Switzerland	Ireland
United Arab Emirates		Malta
		Norfolk Islands
		Norway
		Puerto Rico
		Sweden
		Virgin Islands

Source: <http://apps.fao.org/lim500/showareas.pl/>

FUTURE DIRECTIONS

Opportunities for and constraints to improving the productivity, sustainability and viability of farming systems are often specific to particular agro-climatic (and agro-ecological) zones. Most of these zones traverse many countries, so that research that is relevant to a particular zone and country may well be relevant to many other countries. It is therefore important that the boundaries of the different zones, and the soil and vegetation types, livestock populations and human activities associated with each zone, are clearly defined and documented. The advent of electronic databases, simulation models, remote sensing and geographic information systems are powerful tools for facilitating this process.

National and regional data are not necessarily accurate, and while they are the best available, some efforts should be made to gather field information to substantiate them. This is because wide-ranging decisions are likely to be based on this information, and on studies such as this one that have relied heavily on FAO and associated data. There is also an increasing need for accurate subnational data, as projects targeted to specific regions and issues become more common. This may well require more field work, but the highest priority is to use technologies that can predict, interpolate and/or extrapolate resource distributions from available data.

Advantage should be taken of the considerable opportunities for collaboration with groups such as the FAO, ILRI, CIAT, ERGO Consulting (Oxford University) to improve and make use of the international datasets on livestock numbers and productivity in different agro-ecological zones throughout the developing world. These groups have the expertise and information technology resources, particularly models and geographic information systems. There should be substantial scope for collaborative studies throughout much of Asia and the Pacific, possibly involving ILRI and national governments.

Definition of agro-climatic zones will be determined for some time according to length of growing period, although Australia (and in particularly the Centre for Resource and Environmental Studies at the Australian National University) is at the forefront of improving that definition through the use of basic growth models. There is a need to apply these techniques in other countries of interest, as well as make digitised zone boundaries more generally available, and better integrated with pasture, crop and livestock datasets.

ACIAR may not wish to commit itself to in-house development of models and geographic information systems. Opportunities for outsourcing such work exist, both locally and internationally, and should be taken advantage of.

Methods to aid research prioritisation are continuing to evolve, becoming ever more reliant on quantitative data and associated tools. The coefficients proposed in this study to represent pre- and postharvest technology spillovers, and research and extension capacity, are estimates that attempt to synthesise the situation for often complex and heterogeneous collections of technologies within a wide variety of countries and environmental, socioeconomic and cultural circumstances. Case studies for testing and refining these in specific countries and agro-climatic zones are advocated, in consultation with local expertise.

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REFERENCES

- Anon. 1992. Assessment of animal agriculture in sub-Saharan Africa. Morrilton, Arkansas, Winrock Institute for Agricultural Development, 162p.
- Behnke, R. 1985. Measuring the benefits of subsistence versus commercial livestock development in Africa. *Agricultural Systems*, 16, 109–135.
- Bennison, J.J., Barton, D. and Jaitner, J. 1997. The production objectives and feedings strategies of ruminant livestock owners in the Gambia: implications for policy makers. *Agricultural Systems*, 55, 425–444.
- Beintema, N.M., Pardey, P.G. and Roseboom, J. 1994a. Statistical brief on the national agricultural research system of Cape Verde. International Service for National Agricultural Research.
- 1994b. Statistical brief on the national agricultural research system of Namibia. International Service for National Agricultural Research.
- 1995a. Statistical brief on the national agricultural research system of Lesotho. International Service for National Agricultural Research.
- 1995b. Statistical brief on the national agricultural research system of Mauritius. International Service for National Agricultural Research.
- 1995c. Statistical brief on the national agricultural research system of Sudan. International Service for National Agricultural Research.
- 1995d. Statistical brief on the national agricultural research system of Swaziland. International Service for National Agricultural Research.
- 1996. Statistical brief on the national agricultural research system of Togo. International Service for National Agricultural Research.
- Belbin, L. 1987. The use of non-hierarchical allocation methods for clustering large sets of data. *Australian Journal of Computing*, 19, 32–41.
- Booth T.H. 1990. Mapping regions climatically suitable for particular species at the global scale. *Forest Ecology and Management*, 36, 47–60.
- Bowman, P.J., Fowler, D.G., Wysel, D.A. and White, D.H. 1989. Evaluation of a new technology when applied to sheep production systems: Part II. Realtime ultrasonic scanning of ewes in midpregnancy. *Agricultural Systems*, 29, 287–323.
- Cochemé J. and Franquin P. 1967. An agroclimatology survey of a semi-arid area in Africa, south of the Sahara. *World Meteorological Organization*, 86, No. 210, TP 110
- Coleman, D.C., and Hendrix, P.F. 1988. Agroecosystem processes. In: L.R. Pomeroy, L.R. and Alberts, J.J., ed., *Concepts of Ecosystem Ecology: A Comparative View*. New York, NY, USA, Springer-Verlag, 149–170.
- Corbett, J. D. 1996. The changing face of agroecosystem characterization: models and spatial data, the basis for robust agroecosystem characterization. National Center For Geographic Information and Analysis, Proceedings, Third International Workshop/Conference on the Integration of GIS and Environmental Modeling, Santa Fe, New Mexico, January, 1996.
http://www.sbg.ac.at/geo/idrisi/GIS_environmental_modeling/sf_papers/corbett/corbett.htm
- Corbett, J.D., O'Brien, R.F., Kruska, R.J. and Muchugu, E.I. 1995. Agricultural environments of the Greater Horn of Africa—a database and map set for disaster mitigation. 9p., 31 maps, plus database.
- Davis, J. and Lubulwa, G. 1995. Integration of research evaluation analysis into research institution decision-making: an overview of progress at ACIAR. Australian Centre for International Agricultural Research, Working Paper No. 17.
- Falconi, C.A. and Pardey, P.G. 1993. Statistical brief on the national agricultural research systems of Colombia. International Service for National Agricultural Research.
- FAO 1978–81. Reports of the agro-ecological zones project. *World Soil Resources Reports No. 48*, Vol.1—Africa, Vol. 2—Southwest Asia, Vol. 3—South and Central America, Vol. 4—Southeast Asia, Food and Agriculture Organization of the United Nations, Rome, Italy.
- 1996a. Livestock geography; a demonstration of GIS techniques applied to global livestock systems and populations. Consultant report by William Wint, Food and Agriculture Organization, Rome, Italy, April 1996, 77 pp.

- 1996b. Livestock geography II; a further demonstration of GIS techniques applied to global livestock systems, populations and productivity. Consultant Report by William Wint, Food and Agriculture Organization, Rome, Italy, August 1996, 90 pp.
- 1997. Ecozones, farming systems and priority areas for Tsetse control in East, West and Southern Africa. Consultant report by William Wint, David Rogers and Tim Robinson, Food and Agriculture Organization, Rome, Italy, February 1997, 44 pp.
- 1998. Predictions of cattle density, cultivation levels and farming systems in Kenya. Consultant report by William Wint and David Rogers, Food and Agriculture Organization, Rome, Italy, January 1998, 23 pp.
- FAO/OIE/WHO 1997. Animal health yearbook. FAO Animal Production and Health Series 36, Food and Agriculture Organization, Office International des Epizooties, World Health Organization.
- Fischer, G., de Pauw, E., van Velthuisen, H., Nachtergaele, F. and Antoine, J. 1995. A provisional world climatic resource inventory based on the length-of-growing-period concept. Paper presented at the NASREC Conference, 5–12 November 1995, Wageningen, Netherlands
- Fitzpatrick, E.A. and Nix, H.A. 1970. The climatic factor in Australian grassland ecology. In: Milton Moore, R., ed., Australian grasslands. Canberra, Australian National University Press, 3–26.
- Frank, B.R. 1995. Constraints limiting innovation adoption in the north Queensland beef industry. II. Non-adoption is an intelligent response to environmental circumstances. *Agricultural Systems*, 47, 323–346.
- 1997. Adoption of innovations in the North Queensland beef industry. III. Implications for extension management. *Agricultural Systems*, 55, 347–358.
- Hong, Yan, Booth, T.H. and Zuo, H. 1996. GREEN—a climatic mapping programs for China and its use in forestry. In: Booth, T.H., ed., Matching trees and sites. Canberra, ACIAR Proceedings No. 63, 24–29.
- Hutchinson, M.F. 1984. A summary of some surface fitting and contouring programs for noisy data. Consulting report No. ACT 841. Canberra: CSIRO Division of Mathematics and Statistics and Division of Water and Land Resources, 24p.
- 1989a. A new objective method for spatial interpolation of meteorological variables from irregular networks applied to the estimation of monthly mean solar radiation, temperature, precipitation and windrun. CSIRO Division of Water and Land Resources, Technical Memorandum 89/5, Canberra: CSIRO, 10 p.
- 1989b. A new procedure for gridding elevation and stream line data with automatic removal of spurious pits. *Journal of Hydrology*, 106, 211–232.
- 1991. The application of thin plate smoothing splines to continent-wide data assimilation. In: Jasper, J.D., ed., Data assimilation systems, Bureau of Meteorology Research Centre Research Report No. 27, Bureau of Meteorology, Melbourne, pp. 104–113.
- Hutchinson, M.F., Nix, H.A. and McMahon, J.P. 1992. Climate constraints on cropping systems. In: Pearson, C.J., ed., Field crop ecosystems of the world. Elsevier, 37–58.
- Kannangara, Ratnaseeli 1998. An agroclimatic analysis of Sri Lanka. PhD thesis, Australian National University, Canberra (submitted).
- Köppen, W. 1936. Das Geographische System der Klimate. In: Handbuch der Klimatologie I. Berlin, Gebrüder Borntraeger, C, 1–44.
- Kruska, R.L., Perry, B.D. and Reid, R.S. 1995. Recent progress in the development of decision support systems for improved animal health. In: Proceedings of the Africa GIS '95 meeting, 'Integrated Geographic Information Systems Useful for a Sustainable Management of Natural Resources in Africa', March 6–9, Abidjan, Ivory Coast.
- Le Houérou, H.N., Popov, G.F. and See, L. 1993. Agro-bioclimatic classification of Africa. FAO Meteorology Series No. 6, 227p.
- Li, S.K. 1993. Agroclimatic resources and agricultural distribution patterns. In: Cheng, C., ed., Climate and agriculture in China. Beijing, China Meteorological Press, 30–69.
- Mazzucato, V. 1994a. Statistical brief on the national agricultural research system of Burkina Faso. International Service for National Agricultural Research.
- 1994b. Statistical brief on the national agricultural research system of Mali. International Service for National Agricultural Research.
- Mazzucato, V. and Ly, M.E.H. 1994. Statistical brief on the national agricultural research system of Senegal. International Service for National Agricultural Research.

- Mazzucato, V. and Ly, S. 1993. Statistical brief on the national agricultural research system of Niger. International Service for National Agricultural Research.
- Morley, F.H.W. and Spedding, C.R.W. 1968. Agricultural systems and grazing experiments. *Herbage Abstracts*, 38, 279–287.
- Morley, F.H.W. and White, D.H. 1985. Modelling biological systems. In: Remenyi, J.V., ed., *Agricultural systems research for developing countries*. Canberra, ACIAR Proceedings No. 11, 60–69.
- Nachtergaele F.O. and Bruggeman H.Y. 1986. Methodology for regional analysis of physical potential for crop production. AG:GCP/RAS/107/JPN Field Document 5. Food and Agriculture Organization of the United Nations, Bangkok, Thailand.
- Nix, H.A. 1981. Simplified simulation models based on specified minimum data sets: the CROPEVAL concept. In: Berg, A., ed., *Application of remote sensing to agricultural production forecasting* Rotterdam, Balkema, 151–169.
- Odum, E.P. 1969. The strategy of ecosystem development. *Science*, 164, 262–270.
- Pardey, P.G. and Roseboom, J. 1989. ISNAR Agricultural Research Indicator Series. A global data base on national agricultural research systems. Cambridge University Press, Cambridge, 547 pp.
- Ridder, N. de and Wagenaar, K. 1986. Energy and protein balances in traditional livestock systems and ranching in eastern Botswana. *Agricultural Systems*, 20, 1–16.
- Roseboom, J. and Pardey, P.G. 1993a. Statistical brief on the national agricultural research system of Botswana. International Service for National Agricultural Research.
- 1993b. Statistical brief on the national agricultural research system of Kenya. International Service for National Agricultural Research.
- 1993c. Statistical brief on the national agricultural research system of Malawi. International Service for National Agricultural Research.
- 1993d. Statistical brief on the national agricultural research system of Rwanda. International Service for National Agricultural Research.
- 1994a. Statistical brief on the national agricultural research system of Ghana. International Service for National Agricultural Research.
- 1994b. Statistical brief on the national agricultural research system of Madagascar. International Service for National Agricultural Research.
- 1994c. Statistical brief on the national agricultural research system of Côte d'Ivoire. International Service for National Agricultural Research.
- 1995. Statistical brief on the national agricultural research system of Zambia. International Service for National Agricultural Research.
- Roseboom, J., Beintema, N. and Pardey, P.G. 1993. Statistical brief on the national agricultural research system of Ethiopia. International Service for National Agricultural Research.
- Roseboom, J., Beintema, N.M., Pardey, P.G. and Oyedipe, E.O. 1994. Statistical brief on the national agricultural research system of Nigeria. International Service for National Agricultural Research.
- Roseboom, J., Pardey, P.G. Beintema, N.M., and Mudimu, G.D. 1995a. Statistical brief on the national agricultural research system of Zimbabwe. International Service for National Agricultural Research.
- Roseboom, J., Pardey, P.G., von Bach, H.S. and van Zyl, J. 1995b. Statistical brief on the national agricultural research system of South Africa. International Service for National Agricultural Research.
- Scoones, I. 1992. The economic value of livestock in the communal areas of southern Zimbabwe. *Agricultural Systems*, 39, 339–359.
- Séré, C., Steinfeld, H. and Groeneweld, J. 1996. World livestock production systems: current status, issues and trends. FAO Animal Production and Health Paper No. 127.
- Slingenbergh, J. and Wint, W. 1997. Livestock geography and land use. Proceedings of the Livestock & Environment Conference, June 1997, Wageningen, Netherlands.
- State Meteorological Administration of China 1978. Climate Atlas of the People's Republic of China. Beijing, China Map Press [in Chinese].
- Thulstrup, E.W. 1994. Scientific research for development. Human Resources Operations Working Paper No. 25, World Bank, Washington.

- Vernon, R. 1989. Directory of research workers in agriculture and related sciences. CAB International, Wallingford, UK 490p.
- White, D.H. 1998. A feasibility study to refine the agro-climatic zones of different livestock commodities. Report to ACIAR by ASIT Consulting.
- Zuo, Heping 1996. Agroclimatic analysis for mainland east Asia by a GIS approach. PhD thesis, Australian National University, 264p.
- Zuo, H., Hutchinson, M.F., McMahon, J.P. and Nix, H.A. 1996a. Developing a mean monthly climatic database for China and south-east Asia. In: Booth, T.H., ed., Matching trees and sites Canberra, ACIAR Proceedings No. 63, 10–17.
- Zuo, H., McMahon, J.P., Nix, H.A. and Hutchinson, M.F. 1996b. A GIS-based agroclimatic classification for mainland east Asia. In: Proceedings of the Second Australian Conference on Agricultural Meteorology, The University of Queensland, 1–4 October 1996, 98–101.

APPENDIX 1: AGRICULTURAL RESEARCH INDICATORS

AFGHANISTAN

UNESCO Education indicators 1995:

Third level of education	1.7%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

ALGERIA

ISNAR 1985 (Pardey and Roseboom 1989): 44 PhD, 93 MSc, 168 BSc = 305

Institutions include Centre National de la Recherche Zootechnique (CNRZ), Centre National de la Recherche Agronomique (CNRA), Centre de Recherche sur les Zones Arides (CRZA), Institut de la Santé Animale (INSA), Institut Technique de l'Elevage Bovin et Ovin (ITEBO).

FAO/OIE/WHO 1995:

Total veterinarians	2817
.. in labs, universities, etc.	280
Total animal health aux.	501

UNESCO Education indicators 1995:

Third level of education	12.0%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

ANGOLA

Instituto de Investigação Agronómica (IIA), Instituto de Investigação Veterinária (IIV); both under the Ministry of Agriculture.

ISNAR 1983: 15 BSc + 13 Expts

FAO/OIE/WHO 1995:

Total veterinarians	104
.. in labs, universities, etc.	28
Total animal health aux.	323

UNESCO Education indicators 1995:

Third level of education	0.6%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

ARGENTINA

ISNAR 1985 (Pardey and Roseboom 1989):

243 postgraduates, 876 BSc = 1119

Instituto Nacional de Tecnologia Agropecuaria (INTA)

FAO/OIE/WHO 1995:

Total veterinarians	10000
.. in labs, universities, etc.	2000
Total animal health aux.	2590

UNESCO Education indicators 1995:

Third level of education	39.3%
Education \$s as % of GNP	4.5
Education \$s as % gov't spending	15.0

BANGLADESH

Bangladesh Agricultural Research Council (BARC)

Bangladesh Agricultural Research Institute (BARI)

Bangladesh Agricultural Research University (BAU)

ISNAR 1986 (Pardey and Roseboom 1989): 131 PhD, 732 MSc, 289 BSc = 1152; includes 49 researchers at BARC, 362 (possibly part-time) researchers at BAU and 92 at other universities.

CABI 1989:

3 Agricultural Universities with 22 professors and assoc. professors in animal science or veterinary science, including 6 poultry and 2 dairy specialists.

No livestock specialists cited in BARC and BARI

BARBADOS

ISNAR 1985 (Pardey and Roseboom 1989):

3 PhD, 11 MSc, 29 BSc = 43 + 6 Expts

includes Research Division of the Ministry of Agriculture, Food and Consumer Affairs only.

The Barbados Unit of the Caribbean Agricultural Research and Development Unit (CARDI) contains 2 MSc and 2 BSc (1985)

FAO/OIE/WHO 1995:

Total veterinarians	15
.. in labs, universities, etc.	1
Total animal health aux.	9

UNESCO Education indicators 1995:

Third level of education	29.4%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

BHUTAN**FAO/OIE/WHO 1995:**

Total veterinarians	29
.. in labs, universities, etc.	14
Total animal health aux.	339

UNESCO Education indicators 1995:

Third level of education	0.2%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

BOLIVIA**ISNAR 1983** (Pardey and Roseboom 1989):

2 PhD, 31 MSc, 54 BSc = 87 + 17 Expats

Instituto Boliviano de Tecnología Agropecuaria (IBTA).

Another 32 researchers in Centro de Investigaciones de Agricultura Tropical (CIAT)

FAO/OIE/WHO 1995:

Total veterinarians	1100
.. in labs, universities, etc.	89
Total animal health aux.	0

UNESCO Education indicators 1995:

Third level of education	23.7%
Education \$s as % of GNP	6.6
Education \$s as % gov't spending	–

BOTSWANA

Agricultural research falls under the responsibility of the Department of Agricultural Research (DAR) of the Ministry of Agriculture (MOA); includes the Animal Production and Range Research Unit (APRU).

ISNAR 1986 (Pardey and Roseboom 1989): 1 PhD, 8 MSc, 6 BSc = 15 + 19 Expats

ISNAR 1991 (Roseboom and Pardey 1993a): MOA Department of Agricultural Research (crops, livestock, range land, natural resources) 26 staffed research sites—31.9 national researchers, 13.7 Expatriates = 45.5 FTEs.

MOA Department of Animal Production and Health, National Veterinary Laboratory—13.0 national researchers, 6.0 Expatriates = 19.0 (1.0 FTEs)

Total agricultural researchers = 4.6 PhD, 19.9 MSc, 12.2 BSc = 36.8 + 17,1 Expats = 53.9

Livestock research was 16.2 FTEs, 30.0% of the total.

276,000 farmers, with 195.1 researchers per million farmers

Research expenditure is 3.58% of Ag GDP.

CABI 1989: 16 in Animal Production Unit—including animal scientists, 3 dairy specialists, and rangeland scientists.

FAO/OIE/WHO 1995:

Total veterinarians	39
.. in labs, universities, etc.	15
Total animal health aux.	1498

UNESCO Education indicators 1995:

Third level of education	
Education \$s as % of GNP	9.6
Education \$s as % gov't spending	20.5

BRAZIL

ISNAR 1985 (Pardey and Roseboom 1989): 651 PhD, 1896 MSc, 1314 BSc = 3861;+ 31 Expats in 1983 (1650 in EMBRAPA)

EMBRAPA is the major agricultural research organization in Brazil, comprising nearly all agricultural research at the Federal level. Also, a significant amount of research is performed at the State level.

Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation).

FAO/OIE/WHO 1995:

Total veterinarians	30292
.. in labs, universities, etc.	574
Total animal health aux.	8157

UNESCO Education indicators 1995:

Third level of education	11.5%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

BURKINA FASO

ISNAR 1984 (Pardey and Roseboom 1989): 55 researchers + 55 Expats

Institut Burkinabé de Recherche Agronomique et Zootechnique (IBRAZ)

Institut Voltaïque de Recherches Agronomiques et Zootechniques (IVRAZ)

Laboratoire de Diagnostic et des Recherches Vétérinaires (LDRV)

ISNAR 1991 (Mazzucato 1994a): Institut d'Etudes et Recherches Agricoles (including livestock)—56 nationals and 17 expatriates, making 73.0 FTEs

Within the Ministère de l'Agriculture et des Ressources Animales, the Laboratoire National d'Elevage with 4 nationals (2.8 FTEs).

4.1 million farmers, with 35.0 researchers per million farmers.

Research expenditure = 0.84% of Ag GDP.

39.2 PhD, 55.7 MSc, 3.5 BSc = 98.3 FTEs + 21.7 expatriates = 120.0

Livestock research = 12.1 FTEs = 8.5% of total agricultural research expenditure (incl. fisheries, forestry, crops, livestock, natural resources)

FAO/OIE/WHO 1995:

Total veterinarians	133
.. in labs, universities, etc.	16
Total animal health aux.	394

UNESCO Education indicators 1995:

Third level of education	1.1%
Education \$s as % of GNP	3.6
Education \$s as % gov't spending	11.1

BURMA

ISNAR 1984 (Pardey and Roseboom 1989): 8 PhD, 24 MSc, 235 BSc = 267 Agricultural Research Institute (ARI); Applied Research Division (ARD)

BURUNDI

ISNAR 1983 (Pardey and Roseboom 1989): 1 PhD, 23 MSc, 9 BSc = 33 + 26 Expats

Refers to Institut des Sciences Agronomiques du Burundi (ISABU) only. Other institutions include Laboratoire Vétérinaire (LV) and Institut de Recherche Agronomique et Zootechnique (IRAZ, with Rwanda and Zaire), and the Faculty of Agriculture.

UNESCO Education indicators 1995:

Third level of education	0.9%
Education \$s as % of GNP	2.8
Education \$s as % gov't spending	–

CAMEROON

ISNAR 1983 (Pardey and Roseboom 1989): 16 PhD and 93 MSc; 185 researchers in total in 1986 + 60 Expats

Ecole Fédérale Supérieure d'Agriculture (EFSA) Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux (IEMVT)

Institut des Recherche Zootechniques (IRZ)

FAO/OIE/WHO 1995:

Total veterinarians	175
.. in labs, universities, etc.	14
Total animal health aux.	340

UNESCO Education indicators 1995:

Third level of education	3.9%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

CAPE VERDE

ISNAR 1983 (Pardey and Roseboom 1989):

1 PhD, 4 MSc, 6 BSc = 11 + 3 Expats.

Instituto Nacional de Investigação Agrária Amílcar Cabral (INIAAC)

ISNAR 1991 (Beintema et al. 1994a):

Instituto Nacional de Investigação Agrária (INIA) (includes livestock research) has 6 staffed sites with 20 national researchers and 8 Expats. The Centro de Desenvolvimento Pecuária (CDP) focussed exclusively on animal production had 4 FTEs. No university level training facilities are available within the country.

Economically active agricultural population of 60,000 with 500 researchers per million.

Research expenditure is 6.3 % of AgGDP

2 PhD, 18 MSc, 0 BSc = 20 + 8 Expats. (high proportion of female researchers .. ~40 %)

Livestock research accounts for 10.5 % of total research (4.0 FTEs).

FAO/OIE/WHO 1995:

Total veterinarians	11
.. in labs, universities, etc.	0
Total animal health aux.	340

CENTRAL AFRICAN REPUBLIC

Estimates vary between 28 and 93.

Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux (IEMVT)

UNESCO Education indicators 1995:

Third level of education	1.4%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

CHAD

ISNAR 1994 (Pardey and Roseboom 1989):

20 researchers in 1984

Institut d'Elevage et de Médecine

Vétérinaire des Pays Tropicaux (IEMVT)

Laboratoire de Recherches Vétérinaires et Zootechniques de Farcha (LRVZ)	
Institut d'Enseignement Zootechnique et Vétérinaire d'Afrique Centrale (IEZVAC)	
FAO/OIE/WHO 1995:	
Total veterinarians	166
.. in labs, universities, etc.	15
Total animal health aux.	423
UNESCO Education indicators 1995:	
Third level of education	0.8%
Education \$s as % of GNP	2.2
Education \$s as % gov't spending	–

CHILE

ISNAR 1984 (Pardey and Roseboom 1989): 42 PhD, 66 MSc 168 BSc = 276
Includes Instituto de Investigaciones Agropecuarias (INIA) and the Faculties of Agriculture at the universities. They exclude veterinary research, basic university research, and other organisations such as Instituto de la Patagonia, and the Instituto Nacional de Investigación de Recursos Naturales.

FAO/OIE/WHO 1995:

Total veterinarians	2412
.. in labs, universities, etc.	237
Total animal health aux.	134

UNESCO Education indicators 1995:

Third level of education	28.2%
Education \$s as % of GNP	2.9
Education \$s as % gov't spending	14.0

CHINA PR

ISNAR 1985 (Pardey and Roseboom 1989): total of 33,454 agric. science graduates—though very few at the PhD or equivalent level (a mid-1975 estimate of 180,000 agricultural scientists probably includes many that were poorly trained). In 1983 there were 669 animal breeding stations, 768 veterinary stations and 14,694 extension stations.

Academia Sinica, the national scientific body, also administers national institutes engaged in agricultural and related research.

FAO/OIE/WHO 1995:

Total veterinarians	113748
.. in labs, universities, etc.	38458
Total animal health aux.	276940

UNESCO Education indicators 1995:

Third level of education	5.3%
Education \$s as % of GNP	2.3
Education \$s as % gov't spending	–

COLOMBIA

ISNAR 1985 (Pardey and Roseboom 1989): 47 PhD, 196 MSc, 262 BSc = 505

Includes Instituto Colombiano Agropecuario (ICA), and Instituto Nacional de los Recursos Naturales Renovables y del Ambiente (INDERENA)

Centro Internacional de Agricultura Tropical (CIAT) based in Cali.

ISNAR 1991 (Falconi and Pardey 1993):

ICA (includes livestock) has 25 research sites with 438 researchers (438 FTEs)

2.1 million farmers with 375.4 researchers per million

Research expenditure is 0.47 % of Ag GDP. 129 PhD, 365 MSc, 271 BSc (+ 12 on leave) = 777

The Colombian Enterprise for Veterinary Products (VECOL) had a total of 9 staff with 100% livestock focus, ICA with 438 researchers had a 23 % livestock focus (101 researchers). This suggests that 110 out of 777 researchers were working on livestock = 14 %.

FAO/OIE/WHO 1995:

Total veterinarians	9226
.. in labs, universities, etc.	2317
Total animal health aux.	508

UNESCO Education indicators 1995:

Third level of education	17.2%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

CONGO

ISNAR 1994 (Pardey and Roseboom 1989): 40 researchers in 1984 + 40 Expats

Centre de Recherche Vétérinaire et Zootechnique (CRVZ)

UNESCO Education indicators 1995:

Third level of education	2.3%
Education \$s as % of GNP	5.9
Education \$s as % gov't spending	14.7

COOK ISLANDS

ISNAR 1986: (Pardey and Roseboom 1989): 1 MSc, 1 BSc + 2 Expats

NZ played a dominant role in agricultural research; mainly through the former DSIR.

COSTA RICA

ISNAR 1980: (Pardey and Roseboom 1989): 114 researchers in 1980—Department for Agricultural Research in the Ministerio de Agricultura y Ganadería (MAG, Agriculture and Livestock)

FAO/OIE/WHO 1995:

Total veterinarians	510
.. in labs, universities, etc.	25
Total animal health aux.	29

UNESCO Education indicators 1995:

Third level of education	32.6%
Education \$s as % of GNP	4.5
Education \$s as % gov't spending	19.8

CÔTE D'IVOIRE

ISNAR 1985 (Pardey and Roseboom 1989): 71 researchers and 145 Expats
Many institutes including Centre Suisse de Recherches Scientifiques en Côte d'Ivoire, Institut d'Élevage et de Médecine Vétérinaire des Pays Tropicaux (IEMVT), Institut des Savannes (IDESSA) ; France very involved.

ISNAR 1992 (Roseboom and Pardey 1994c): IDESSA has 7 staffed research sites, 61 national researchers and 13 Expats = 74 FTEs

The Ecole Nationale Supérieure Agronomique (crops and livestock) ha 44 nationals and 7 Expats = 15.3 FTEs

The Université Nationale de Côte d'Ivoire—Département Biologie et Physiologie Animale has 34 nationals and 1 Expat = 11.7 FTEs

There are 2.6 million farmers (econ. active agr. population) with 103.0 researchers per million e.a.a.p.

Research expenditure is 0.94% of AgGDP.

There are at least 48.8 PhD, 78.2 MSc, 16.0 BSc + unspecified graduates = 221.0 + 92.5 Expats = 313.5

Livestock research accounted for 8.1% of total research expenditure or 24.2 FTEs

FAO/OIE/WHO 1995:

Total veterinarians	131
.. in labs, universities, etc.	33
Total animal health aux.	883

UNESCO Education indicators 1995:

Third level of education	4.6%
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

CUBA

ISNAR 1984: (Pardey and Roseboom 1989) 2191 researchers in 1984.
Ministry of Agriculture; Instituto de Ciencia Animal (ICA); Instituto de Ciencia Agrícola (INCA)

FAO/OIE/WHO 1995:

Total veterinarians	0
.. in labs, universities, etc.	—
Total animal health aux.	0

UNESCO Education indicators 1995:

Third level of education	12.7%
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

DOMINICAN REPUBLIC

ISNAR 1983 (Pardey and Roseboom 1989): 2 PhD, 29 MSc, 105 BSc = 136 within Ministry of Agriculture

FAO/OIE/WHO 1995:

Total veterinarians	900
.. in labs, universities, etc.	0
Total animal health aux.	116

UNESCO Education indicators 1995:

Third level of education	26.0%
Education \$s as % of GNP	1.9
Education \$s as % gov't spending	13.2

ECUADOR

ISNAR 1986 (Pardey and Roseboom 1989): 5 PhD, 67 MSc and 153 BSc = 225
Instituto Nacional de Investigaciones Agropecuaria (INIAP) only.

Also 42 researchers at a veterinary laboratory, and 11 graduates in the faculty of agronomy and veterinary science at the Universidad Técnica de Machala.

FAO/OIE/WHO 1995:

Total veterinarians	70
.. in labs, universities, etc.	10
Total animal health aux.	63

UNESCO Education indicators 1995:

Third level of education	23.4%
Education \$s as % of GNP	3.4
Education \$s as % gov't spending	—

EGYPT

ISNAR 1985 (Pardey and Roseboom 1989):
800 PhD, 1200 MSc, 3000 BSc = 5000
Agricultural Research Centre, within the
Ministry of Agriculture.

Does not include the Agricultural Research
Division of the National Research Centre
(600 researchers, 200 with PhDs).

FAO/OIE/WHO 1995:

Total veterinarians	29244
.. in labs, universities, etc.	5000
Total animal health aux.	15950

UNESCO Education indicators 1995:

Third level of education	17.7%
Education \$s as % of GNP	5.6
Education \$s as % gov't spending	13.8

EL SALVADOR

ISNAR 1980 (Pardey and Roseboom 1989):
106 researchers in 1980

Centro Nacional de Tecnología Agropecuaria
(CENTA)

Centro de Recursos Naturales (CENREN)

FAO/OIE/WHO 1995:

Total veterinarians	201
.. in labs, universities, etc.	14
Total animal health aux.	36

UNESCO Education indicators 1995:

Third level of education	17.7%
Education \$s as % of GNP	2.2
Education \$s as % gov't spending	-

ETHIOPIA

ISNAR 1986 (Pardey and Roseboom 1989):
17 PhD, 60 MSc, 153 BSc = 230 + 10
Expats

Institute of Agricultural Research (IAR)

Also, Institut d'Élevage et de Médecine
Vétérinaire des Pays Tropicaux (IEMVT)
had 8 researchers

ISNAR 1991 (Roseboom et al 1993): IAR
has 24 staffed research sites, with 272
national researchers + 16 Expats = 288
FTEs.

The Arsi Regional Development UNIT
(ARDU) (food crops, livestock, forestry) =
8 FTEs

National Veterinary Institutes (2.7 FTEs)
and the National Tsetse and
Trypanosomiasis Investigation Centre.
Livestock research also at the Alemaya
University of Agriculture, the Addis Ababa
University (Faculty of Veterinary
Medicine), and Asmara University (Faculty
of Arid Zone Agriculture)

Total researchers = 28.9 PhD, 108.8 MSc,
225.6 BSc = 363.3 + 23.5 Expats.

18.2% of agricultural researchers focused
on livestock production (70.5 FTEs)

15.7 million farmers (econ. act. agr.) with
24.7 researchers per million.

Research expenditure is 0.58% of Ag GDP.

FAO/OIE/WHO 1995:

Total veterinarians	541
.. in labs, universities, etc.	73
Total animal health aux.	2667

UNESCO Education indicators 1995:

Third level of education	0.7%
Education \$s as % of GNP	4.7
Education \$s as % gov't spending	13.0

FIJI

Ministry of Agriculture and Fisheries,
including Animal Health and Production
Division

ISNAR 1986 (Pardey and Roseboom 1989):
2 PhD, 11 MSc, 27 BSc = 40 + 10 Expats

CABI 1989: Vets include the Permanent
Secretary and 2 listed in Animal Health and
Production Division. 3 graduates listed in
animal production.

FAO/OIE/WHO 1995:

Total veterinarians	8
.. in labs, universities, etc.	0
Total animal health aux.	184

GABON

ISNAR 1985 (Pardey and Roseboom 1989): 3
postgraduates, 7 BSc = 10 + 14 Expats
Significant withdrawal of French agricultural
research

GAMBIA

ISNAR 1984 (Pardey and Roseboom 1989): 45 researchers in 1984—in Agricultural Research Services of the Department of Agriculture, and the Department of Animal Health.

CABI 1989: no animal scientists listed.

UNESCO Education indicators 1995:

Third level of education	1.8%
Education \$s as % of GNP	5.5
Education \$s as % gov't spending	—

GHANA

ISNAR 1985 (Pardey and Roseboom 1989): 31 PhD, 66 MSc, 42 BSc = 139 +12 Expats includes Animal Research Institute, Division of Veterinary Services, Ministry of Agriculture

Council for Scientific and Industrial Research—the Animal Research Institute (animal production and health) has 4 staffed research sites with 15 national researchers and 1 expatriate (16.0 FTEs).

The Ministry of Agriculture's Veterinary Services Department has 10 sites and 9.0 FTEs.

The Faculties of Agriculture at the University of Ghana, the University of Science and Technology and the University of Cape Coast include livestock in their research focus.

ISNAR 1991 (Roseboom and Pardey 1994a): Total researchers include 19.0 PhD, 20.2 MSc and 1.7 BSc = 40.9

Livestock research accounts for 12.7% of the total = 36.4 FTEs.

2.8 million farmers with 99.7 researchers per million farmers.

Research expenditure is 0.47% of Ag GDP.

CABI 1989: 11 animal scientists or parasitologists at the Animal Research Institute.

23 graduates in the Veterinary Services Department and 5 in the Animal Husbandry Department of the Ministry of Agriculture.

9 graduates in the Animal Science Department of the University of Ghana; 6 animal husbandry and 1 pasture specialist at Legon Research Station.

7 parasitologists in the Department of Zoology.

University of Science and Technology—11 graduates in the Department of Animal Science, including pigs and poultry.

University of Cape Coast—5 graduates in the Animal Science Division.

FAO/OIE/WHO 1995:

Total veterinarians	181
.. in labs, universities, etc.	12
Total animal health aux.	627

UNESCO Education indicators 1995:

Third level of education	1.8%
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

GUATEMALA

ISNAR 1985 (Pardey and Roseboom 1989): 2 PhD, 25 MSc, 101 BSc = 128 + 4 Expats Instituto de Ciencia y Tecnología Agrícola (ICTA)

UNESCO Education indicators 1995:

Third level of education	8.1%
Education \$s as % of GNP	1.7
Education \$s as % gov't spending	18.2

GUINEA

ISNAR 1986 (Pardey and Roseboom 1989): 177 researchers

excludes university and veterinary research

FAO/OIE/WHO 1995:

Total veterinarians	229
.. in labs, universities, etc.	21
Total animal health aux.	356

UNESCO Education indicators 1995:

Third level of education	0.9%
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

GUINEA-BISSAU

ISNAR 1983 (Pardey and Roseboom 1989): 5 MSc, 2 BSc = 7 + 1 Expat .. agronomic research only

GUYANA

ISNAR 1980 (Pardey and Roseboom 1989): 2 PhD, 21 MSc, 33 BSc = 56

Includes Veterinary and Livestock Division, and other Divisions, within the Ministry of Agriculture

Also Caribbean Agricultural Research and Development Institute (CARDI)

CABI 1989:

9 graduates in the Animal Services Division (livestock and veterinary diagnostic services, including dairy and pigs)

FAO/OIE/WHO 1995:

Total veterinarians	33
.. in labs, universities, etc.	3
Total animal health aux.	21

UNESCO Education indicators 1995:

Third level of education	8.8%
Education \$\$ as % of GNP	4.1
Education \$\$ as % gov't spending	8.1

INDIA

Indian Council for Agricultural Research (ICAR)

Agricultural research carried out at both the national and State level. ICAR comprises, as at 1986, 40 national agricultural research institutes, 14 national research centres, >70 All-India coordinated research projects, and 12 national-level general universities. At the State level, agricultural research is conducted within State Agricultural Universities (SAUs) which have been adapted from the US land-grant system. Assumed that 1/3rd of total person-years at SAUs spent on research.

ISNAR 1985 (Pardey and Roseboom 1989): 8389 graduates involved in agricultural research (aggregated data only).

CABI 1989:

Numerous researchers, including livestock researchers, at various institutes and universities, especially dairy and poultry, some in buffalo, pigs, sheep/wool and goats

FAO/OIE/WHO 1995:

Total veterinarians	35865
.. in labs, universities, etc.	2890
Total animal health aux.	67650

UNESCO Education indicators 1995:

Third level of education	6.4%
Education \$\$ as % of GNP	–
Education \$\$ as % gov't spending	–

INDONESIA

Agency for Agricultural Research and Development (AARD)

Ministry of Agriculture

ISNAR 1986 (Pardey and Roseboom 1989): 129 PhD, 235 MSc, 1008 BSc = 1372

FAO/OIE/WHO 1995:

Total veterinarians	4140
.. in labs, universities, etc.	1100
Total animal health aux.	9194

UNESCO Education indicators 1995:

Third level of education	11.3%
Education \$\$ as % of GNP	–
Education \$\$ as % gov't spending	–

IRAN

ISNAR 1982 (Pardey and Roseboom 1989): 493 researchers in 1982

Includes Animal Husbandry Research Institute, and Forest and Rangeland Research Institute, and Safiabad Agricultural Research Centre

UNESCO Education indicators 1995:

Third level of education	16.6%
Education \$\$ as % of GNP	4.0
Education \$\$ as % gov't spending	17.8

IRAQ

ISNAR 1983 (Pardey and Roseboom 1989): 93 PhD, 75 MSc, 374 BSc = 542

State Board for Applied Agricultural Research (SBAAR)

Agriculture and Water Resources Research Centre (AWRRC)

UNESCO Education indicators 1995:

Third level of education	11.2%
Education \$\$ as % of GNP	–
Education \$\$ as % gov't spending	–

ISRAEL

ISNAR 1980 (Pardey and Roseboom 1989): 500 researchers in 1980

Kidron Veterinary Institute, Agricultural Research Organisation

[Vulcani Institute, Hebron University etc.]

Ministry of Agriculture

FAO/OIE/WHO 1995:

Total veterinarians	1010
.. in labs, universities, etc.	117
Total animal health aux.	350

UNESCO Education indicators 1995:

Third level of education	41.1%
Education \$\$ as % of GNP	–
Education \$\$ as % gov't spending	–

JAMAICA

ISNAR 1980 (Pardey and Roseboom 1989): 4 PhD, 23 MSc, 22 BSc = 49. Ministry of Agriculture, includes livestock research

CABI 1989: 9 livestock researchers at Bodles Agricultural Research Station. (cattle, dairy cattle, sheep, goat, rabbits)

FAO/OIE/WHO 1995:

Total veterinarians	56
.. in labs, universities, etc.	6
Total animal health aux.	

UNESCO Education indicators 1995:

Third level of education	7.5%
Education \$s as % of GNP	8.2
Education \$s as % gov't spending	7.7

JORDAN

ISNAR 1984 (Pardey and Roseboom 1989): 18 PhD, 11 MSc, 30 BSc = 59

Department of Agricultural Research and Extension within the Ministry of Agriculture, plus the Faculty of Agriculture at the University of Jordan

UNESCO Education indicators 1995:

Third level of education	17.4%
Education \$s as % of GNP	6.3
Education \$s as % gov't spending	16.6

KAMPUCHEA

FAO/OIE/WHO 1995:

Total veterinarians	162
.. in labs, universities, etc.	32
Total animal health aux.	561

UNESCO Education indicators 1995:

Third level of education	1.6%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

KENYA

ISNAR 1986 (Pardey and Roseboom 1989): 17 PhD, 212 MSc, 275 BSc = 504

Includes all research institutes under the jurisdiction of the Scientific Research Division of the Ministry of Agriculture, the Veterinary Services Department of the Ministry of Agriculture, the Kenya Agricultural Research Institute and, inter alia, the Kenya Veterinary Research Institute.

ISNAR 1991 (Roseboom and Pardey 1993b): Kenya Agricultural Research Institute (KARI) has 34 staffed research sites with 482 national researchers + 50 expatriates = 532 researchers (and FTEs).

The University of Nairobi has Faculties of Agriculture and Veterinary Medicine, and Egerton University has a Faculty of Agriculture (including animal health and production).

Total agricultural researchers include 55.6 PhD, 317.9 MSc, 375.4 BSc and 69.8 Expats. Livestock research accounts for 112.8 FTEs, 13.8% of the total.

7.9 million farmers with 104.2 researchers per million

Research expenditure is 1.76% of Ag GDP.

CABI 1989: At least 31 researchers in the Ministry for Agriculture and Livestock Development, plus veterinary specialists; 11 in the Department of Animal Production at the University of Nairobi, plus 5 in animal physiology and 17 in veterinary pathology and microbiology.

The International Laboratory for Research on Animal Diseases (ILRAD—forerunner to the International Livestock Research Institute, ILRI) had about 30 graduates.

FAO/OIE/WHO 1995:

Total veterinarians	1459
.. in labs, universities, etc.	282
Total animal health aux.	2744

UNESCO Education indicators 1995:

Third level of education	1.5%
Education \$s as % of GNP	7.4
Education \$s as % gov't spending	–

KOREA (REPUBLIC OF)

ISNAR 1983 (Pardey and Roseboom 1989): 155 PhD, 398 MSc, 583 BSc + 237 Expats

Ministry of Agriculture and Fisheries includes Agricultural Science Institute and Veterinary Research Institute, plus Experiment Stations (livestock, alpine, etc.)

FAO/OIE/WHO 1995:

Total veterinarians	8618
.. in labs, universities, etc.	351
Total animal health aux.	

UNESCO Education indicators 1995:

Third level of education	52.0%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

KUWAIT

ISNAR 1986 (Pardey and Roseboom 1989):
2 PhD, 1 MSc, 9 BSc = 12

Agriculture Affairs and Fish Resources
Authority (AAFRA) within the Ministry of
Works

FAO/OIE/WHO 1995:

Total veterinarians	105
.. in labs, universities, etc.	6
Total animal health aux.	129

UNESCO Education indicators 1995:

Third level of education	25.4%
Education \$s as % of GNP	5.6
Education \$s as % gov't spending	—

LAOS, PDR

ISNAR 1987 (Pardey and Roseboom 1989):
Centre National de Recherche
Agronomique (CNRA)—reported to have
62 researchers—3 PhD, 18 MSc, 31BSc and
10 Expats.

FAO/OIE/WHO 1995:

Total veterinarians	65
.. in labs, universities, etc.	17
Total animal health aux.	5345

UNESCO Education indicators 1995:

Third level of education	1.6%
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

LESOTHO

ISNAR 1984 (Pardey and Roseboom 1989):
3 MSc and 6 BSc = 9 + 9 Expats in the
Research Division of the Ministry of
Agriculture.

ISNAR 1991 (Beintema et al. 1995a):
Ministry of Agriculture, Cooperatives and
Marketing has 15 staffed research sites,
including 20 national researchers and 6
Expats = 26 FTEs.

2.0 PhD, 6.0 MSc, 13.0 BSc = 21.0 + 6.0
Expats = 27.0 FTEs

Economically active agricultural population
of 670,000, with 35.8 researchers per
million.

Research expenditure is 1.43 % of Ag GDP.

Livestock accounts for 16.7% of total
research expenditure, or 3 FTEs.

UNESCO Education indicators 1995:

Third level of education	2.5%
Education \$s as % of GNP	5.9
Education \$s as % gov't spending	—

LIBERIA

ISNAR 1984 (Pardey and Roseboom 1989):
5 PhD, 8 MSc, 10 BSc = 2 + 9 Expats
Central Agricultural Experiment Station
(CAES)

UNESCO Education indicators 1995:

Third level of education	3.3%
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

MADAGASCAR

ISNAR 1986 (Pardey and Roseboom 1989):
51 postgraduates, 47 BSc = 98 + 19 Expats
includes Institut d'Élevage et de Médecine
Vétérinaire des Pays Tropicaux (IEMVT)

ISNAR 1991 (Roseboom and Pardey
1994b): Centre National de la Recherche
Appliquée au Développement Rural
(includes research) has 17 staffed sites, 131
nationals and 26 Expats = 157.0
FTEs—includes 12 PhD, 81 MSc and 38
BSc.

The Université d'Antananarivo (includes
livestock) has 34 nationals and 5 Expats
(11.7 FTEs)

4.0 million farmers (econ. active agr.) with
48.2 researchers per million.

Research expenditure is 0.57% of Ag GDP.
Livestock research = 11.5% of total research
(22.7 FTEs)

FAO/OIE/WHO 1995:

Total veterinarians	270
.. in labs, universities, etc.	11
Total animal health aux.	815

UNESCO Education indicators 1995:

Third level of education	2.1%
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

MALAWI

ISNAR 1982 (Pardey and Roseboom 1989):
3PhD, 17 MSc and 64 BSc = 84 + 10 Expats
in the Department of Agricultural Research
within the Ministry of Agriculture only;
excludes the Department of Veterinary
Services, and other Departments.

ISNAR 1991 (Roseboom and Pardey
1993c): Department of Agricultural
Research (includes livestock) has 94
nationals, 12 Expats = 106 FTEs. The
Department of Veterinary Services has 9
nationals and 9 Expats = 18 FTEs.

Bunda College of Agriculture within the University of Malawi includes livestock research and has 27 nationals and 4 Expats (7.8 FTEs) engaged in agricultural research. Total agricultural research = 25.0 PhD, 76.5 MSc, 52.5 BSc = 154.0 + 30.9 Expats = 184.9

Livestock research accounts for 16.5% of total research = 30.5 FTEs.

2.7 million farmers with 67.8 researchers per million.

Research expenditure is 1.66 % of Ag GDP.

CABI 1989:

7 livestock specialists in the Department of Agricultural Research (including dairy and small ruminants; 11 in the Department of Veterinary Services and Animal Industry; 10 in the Livestock Production Department of the University of Malawi.

FAO/OIE/WHO 1995:

Total veterinarians	45
.. in labs, universities, etc.	17
Total animal health aux.	813

UNESCO Education indicators 1995:

Third level of education	0.9%
Education \$s as % of GNP	5.7
Education \$s as % gov't spending	–

MALAYSIA

Malaysian Agricultural Research and Development Institute (MARDI)

Veterinary Research Institute (VRI)

ISNAR 1983 (Pardey and Roseboom 1989): 171 PhD, 358 MSc, 318 BSc = 862; of which 5 PhD, 240 MSc, and 152 BS are in MARDI.

.. also disaggregated data for Sarawak and Sabah

CABI 1989:

5 livestock specialists in MARDI (beef, goats, sheep, pigs, dairy, buffaloes, poultry); about 5 others in government. 23 in the Department of Animal Science at the Universiti Pertanian Malaysia, and 24 in the Veterinary Departments.

FAO/OIE/WHO 1995:

Total veterinarians	919
.. in labs, universities, etc.	4
Total animal health aux.	2215

UNESCO Education indicators 1995:

Third level of education	11.0%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

MALI

ISNAR 1983 (Pardey and Roseboom 1989): 12 PhD, 38 MSc, 196 BSc = 246 + 29 Expats

Various National Research Institutes, the Laboratoire Central Vétérinaire (LCV)

ISNAR 1991 (Mazzucato 1994b): Institut d'Economie Rurale (including livestock) has 7 research sites, 234 nationals + 34 Expats = 268 FTEs

LCV has 23 nationals = 11.5 FTEs.

Institute Polytechnique Rural de Katibogou (crop and livestock sciences) has 125 nationals and 12 Expats (10.9 FTEs) and the Institut Supérieur de Formation en Recherche (crop and livestock sciences) has 14 nationals and 2 Expats (2.2 FTEs).

2.4 million farmers with 127.7 researchers per million.

Research expenditure is 1.04 % of Ag GDP.

Livestock research accounts for 32.3 % of total research (99.5 FTEs)

UNESCO Education indicators 1995:

Third level of education	0.8%
Education \$s as % of GNP	2.2
Education \$s as % gov't spending	–

MAURITANIA

ISNAR 1983 (Pardey and Roseboom 1989): 7 PhD, 4 MSc, 1 BSc = 12

Centre National de l'Elevage et de Recherche Vétérinaire (CNERV)

Centre National de Recherche Agronomique et de Développement Agricole (CNRADA)

UNESCO Education indicators 1995:

Third level of education	4.9%
Education \$s as % of GNP	5.0
Education \$s as % gov't spending	16.1

MAURITIUS

ISNAR 1984 (Pardey and Roseboom 1989): 30 postgraduates and 78 BSc = 108 (83 in MANRE)

From Divisions within the Ministry of Agriculture, Natural Resources and the Environment (MANRE), and the Mauritius Sugar Industries Research Institute.

Some agricultural research undertaken by the School of Agriculture (not included in above data).

ISNAR 1991 (Beintema et al. 1995b): The Ministry of Agriculture, Fisheries and Natural Resources has 17 staffed sites with 72 national researchers = 36.0 FTEs.

There is an economically active agricultural population of 94,000, with 1127.5 researchers per million farmers.

Research expenditure is 2.4% of AgGDP

There are 105.9 FTEs including at least 8.6 PhDs, 27.0 MSc and 23.8 BSc; + 0.2 Expats = 106.1 FTEs

Livestock accounts for 13.3% of total research and 13.5 FTEs.

CABI 1989:

18 in the Veterinary Division and 9 in the Animal Production Division (including sheep, dairy and beef cattle, poultry) of the Ministry; 3 (2 in animal nutrition and 1 in veterinary science) at the University of Mauritius.

FAO/OIE/WHO 1995:

Total veterinarians	46
.. in labs, universities, etc.	1
Total animal health aux.	38

UNESCO Education indicators 1995:

Third level of education	6.3%
Education \$s as % of GNP	4.3
Education \$s as % gov't spending	17.3

MEXICO

ISNAR 1982 (Pardey and Roseboom 1989): 76 PhD, 235 MSc, 799 BSc = 1110

Instituto Nacional de Investigaciones Agrícolas (INIA)

FAO/OIE/WHO 1995:

Total veterinarians	30000
.. in labs, universities, etc.	5700
Total animal health aux.	0

UNESCO Education indicators 1995:

Third level of education	14.1
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

MONGOLIA

FAO/OIE/WHO 1995:

Total veterinarians	3611
.. in labs, universities, etc.	590
Total animal health aux.	624

MOROCCO

ISNAR 1986 (Pardey and Roseboom 1989): 85 postgraduates and 93 BSc = 178

Institut National del la Recherche Agronomique (INRA)

Institut Agronomique et Vétérinaire Hassan II

FAO/OIE/WHO 1995:

Total veterinarians	645
.. in labs, universities, etc.	113
Total animal health aux.	1936

UNESCO Education indicators 1995:

Third level of education	11.2%
Education \$s as % of GNP	4.9
Education \$s as % gov't spending	—

MOZAMBIQUE

ISNAR 1985: 14 BSc + 63 Expats

National Agricultural Research Institute

Institute of Animal Breeding and Reproduction

National Institute for Veterinary Research

FAO/OIE/WHO 1995:

Total veterinarians	49
.. in labs, universities, etc.	0
Total animal health aux.	390

UNESCO Education indicators 1995:

Third level of education	0.5%
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

MYANMAR (BURMA)

FAO/OIE/WHO 1995:

Total veterinarians	2508
.. in labs, universities, etc.	190
Total animal health aux.	682

NAMIBIA

ISNAR 1992 (Beintema et al. 1994b):

Ministry of Agriculture, Water and Rural Development—the Division of Agricultural Investigation (crops and livestock) has 19 staffed research sites with 19 nationals and 2 Expats = 21 FTEs. There is 1 FTE in the Central Veterinary Laboratory.

153,000 farmers (economically active agricultural population) with 417.2 researchers per million

Research expenditure is 3.48% of AgGDP.

Livestock research = 18.8% of total research (12 FTEs).

FAO/OIE/WHO 1995:

Total veterinarians	44
.. in labs, universities, etc.	1
Total animal health aux.	267

UNESCO Education indicators 1995:

Third level of education	8.1%
Education \$s as % of GNP	9.4
Education \$s as % gov't spending	21.3

NEPAL

Ministry of Agriculture includes a Department of Livestock and Animal Health

ISNAR 1983 (Pardey and Roseboom 1989):

16 PhD, 216 MSc, 264 BSc = 496 + 16 Expats

FAO/OIE/WHO 1995:

Total veterinarians	230
.. in labs, universities, etc.	15
Total animal health aux.	1808

NICARAGUA

ISNAR 1980 (Pardey and Roseboom 1989):

10 postgraduates and 47 BSc

Ministry of Agriculture

FAO/OIE/WHO 1995:

Total veterinarians	212
.. in labs, universities, etc.	20
Total animal health aux.	65

UNESCO Education indicators 1995:

Third level of education	10.3%
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

NIGER

ISNAR 1985 (Pardey and Roseboom 1989): 30 researchers

Institut National de Recherches Agronomiques du Niger (INRAN)

Institut d'Élevage et de Médecine Vétérinaire des Pays Tropicaux (IEMVT)

ISNAR 1991 (Mazzucato and Ly 1993):

12.6 PhD, 40.6 MSc, 21.0 BSc and 16.2 expatriates = 90.4 FTEs.

Institut National de Recherche

Agronomiques du Niger (INRAN) has 16 staffed research sites, with 63 national and 9 expatriate staff (crops, livestock, soils, socio-economics, forestry) (72.0 FTEs)

Direction des Centres de Multiplication du Bétail et Stations d'Élevage—focussing on livestock (7.2 FTEs)

Also the Université de Niamey, which appears to have little emphasis on livestock. Since INRAN's creation, USAID has been a major source of funding for agricultural research.

3.5 million farmers, with 29.1 researchers per million farmers

Research expenditure is 0.58% of Ag GDP.

FAO/OIE/WHO 1995:

Total veterinarians	201
.. in labs, universities, etc.	58
Total animal health aux.	945

UNESCO Education indicators 1995:

Third level of education	0.7%
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

NIGERIA

ISNAR 1984 (Pardey and Roseboom 1989):

986 researchers

Institute of Agricultural Research

National Animal Production Research (NAPRI)

National Institute for Trypanosomiasis Research (NIT)

National Veterinary Research Institute (NVRI)

ISNAR 1992 (Roseboom et al. 1994):

NVRI has 13 staffed research sites with 73 national researchers (73.0 FTEs)

NIT has 2 sites with 31 national researchers (31.0 FTEs)

NAPRI has 4 sites with 61 national researchers and 1 expatriate focussing on livestock (62.0 FTEs)

University of Ibadan, Ahmadu Bello University, the University of Maiduguri and the University of Nigeria and numerous other universities all have livestock research—these four have faculties of Veterinary Medicine as well as Agriculture.

27.6 million farmers with 36.1 researchers per million farmers

Research expenditure is 0.18% of AgGDP.

318.7 PhD, 512.4 MSc, 120.6 MSc = 987.0
+ 10.6 Expat = 997.5 FTEs

Livestock account for 23.2% of research
expenditure, and 235.1 FTEs.

CABI 1989:

The National Animal Production Research
Institute, Shika, has 38 livestock
researchers, 8 in pasture agronomy, and 5 in
livestock economics and rural sociology; 7
are devoted to poultry and swine, 10 on
cattle and 5 on small ruminants. NIT has 5
pathologists, 2 vets and 2 parasitologists.

The University of Nigeria has 21 working
on aspects of veterinary science. The
University of Ife has 8 in its School of
Animal Health and Husbandry.

UNESCO Education indicators 1995:

Third level of education	4.0%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

PAKISTAN

Pakistan Agricultural Research Council
(PARC)

ISNAR 1984 (Pardey and Roseboom
1989): 299 PhD, 2181 MSc, 951 BSc =
3431

.. includes 689 university researchers,
including 151 PhDs, 477 MSc, 61 BSc.

FAO/OIE/WHO 1995:

Total veterinarians	2620
.. in labs, universities, etc.	539
Total animal health aux.	6266

UNESCO Education indicators 1995:

Third level of education	3.4%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

PANAMA

ISNAR 1986 (Pardey and Roseboom 1989):
9 PhD, 41 MSc, 90 BSc = 140

Instituto de Investigación Agropecuaria
Panamá (IDIAP)

Also Faculty of Agriculture at the
University of Panama

FAO/OIE/WHO 1995:

Total veterinarians	549
.. in labs, universities, etc.	14
Total animal health aux.	92

UNESCO Education indicators 1995:

Third level of education	30.0%
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Education \$s as % of GNP	–
Education \$s as % gov't spending	–

PAPUA NEW GUINEA

107 researchers listed in the Department of Primary
Industries (DPI) in 1980, of which 22 were in the
livestock branch. This included 65 Expat. In
addition there were 45 agricultural researchers
working outside DPI. Small research projects at the
University of PNG, and the Institute of Technology.

CABI:1989

The Department of Agriculture and Livestock has 7
graduates in the National Veterinary Laboratory at
Kila Kila, 6 at the Monogastric Research Centre, 7 at
the Pastoral Research Centre, Erap (cattle and
pasture agronomy) and 5 at the Sheep Research
Centre at Menifo.

PARAGUAY

ISNAR 1986 (Pardey and Roseboom 1989):
2 PhD, 36 MSc, 74 BSc = 112

Dirección de Investigación y Extensión
Agropecuaria y Forestal (DIEAF)

FAO/OIE/WHO 1995:

Total veterinarians	1240
.. in labs, universities, etc.	195
Total animal health aux.	1603

UNESCO Education indicators 1995:

Third level of education	11.3%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

PERU

ISNAR 1980 (Pardey and Roseboom
1989): 4 PhD, 30 MSc, 239 BSc = 273

Instituto Nacional de Investigación Agraria
y Agroindustrial (INIA), under Ministry of
Agriculture and Food. Also National
Agricultural University, and regional
universities.

UNESCO Education indicators 1995:

Third level of education	31.1
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

PHILIPPINES

Many different agricultural research
organisations, coordinated by the Philippine
Council for Agriculture and Resources
Research and Development (PCARRD).
Ministry of Agriculture (MOA)

Ministry of Natural Resources (MNR)
Commodity Institutes, Colleges and Universities
ISNAR 1977: 76 PhD, 218 MSc, 1096 BSc = 1096
UNESCO Education indicators 1995:

Third level of education	27.9%
Education \$s as % of GNP	2.2
Education \$s as % gov't spending	–

QATAR

ISNAR 1983 (Pardey and Roseboom 1989): 6 BSc
Ministry of Industry and Agriculture
FAO/OIE/WHO 1995:

Total veterinarians	40
.. in labs, universities, etc.	3
Total animal health aux.	11

UNESCO Education indicators 1995:

Third level of education	27.6%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

RWANDA

ISNAR 1985 (Pardey and Roseboom 1989): 26 researchers
Institut des Sciences Agronomiques du Rwanda (ISAR)
ISNAR 1992 (Roseboom and Pardey 1993d): ISAR has 13 staffed research sites with 37 researchers, plus 12 Expats (49 FTEs)
– focuses on crops, livestock, forestry, soils, socioeconomics.
The Université National du Rwanda has 10 researchers, plus 7 Expats. Another institute has 3 staff making a total of 49 nationals and 20 Expats = 69 staff (57 FTEs), made up of 5.8 PhD, 35.2 MSc, 1.0 BSc and 15.1 expatriates.
Large injections of Belgian (1962–76) and World Bank (1986–89) financial support to ISAR; donors still account for two-thirds of the institute's total expenditure.
17% of staff time on livestock research—50% cattle, 35% pastures and forage, 15% goats.
39% of the university's agricultural research is on livestock.
A country total of 10.3 FTEs (18%) is on livestock research.

3.3 million farmers with 17.3 researchers per million farmers
Research expenditure equals 0.58% of Ag GDP.
UNESCO Education indicators 1995:

Third level of education	0.6%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

SAUDI ARABIA

ISNAR 1983 (Pardey and Roseboom 1989): 2 PhD, 12 MSc, 80 BSc = 94 + 77 Expats
includes Range and Animal Development Research Centre
UNESCO Education indicators 1995:

Third level of education	15.8%
Education \$s as % of GNP	5.5
Education \$s as % gov't spending	–

SENEGAL

ISNAR 1984 (Pardey and Roseboom 1989): 129 researchers, + 54 Expats
Institut Sénégalais pur la Recherche Agricole (ISRA)
Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux (IEMVT)
Laboratoire National de l'Elevage et de la Recherche Vétérinaire (LNERV)
ISNAR 1992 (Mazzucato and Ly 1994: ISRA (includes livestock) had 12 staffed research sites with 109 national researchers + 46 Expats = 155.0 FTEs.
Ecole National Supérieure d'Agriculture (including animal husbandry) had 7 nationals and 7 Expats = 3.5 FTEs
2.5 million farmers with 66.1 researchers per million.
Research expenditure is 1.30% of Ag GDP.
Livestock research accounted for 20.1% of research (33.8 FTEs)
UNESCO Education indicators 1995:

Third level of education	3.3%
Education \$s as % of GNP	3.6
Education \$s as % gov't spending	33.1

SOLOMON ISLANDS

ISNAR 1986 (Pardey and Roseboom 1989): 1 MSc, 3 BSc + 9 Expats in the Department of Research of the Ministry of Agriculture and Lands.

CABI 1989: The Ministry of Agriculture and Lands lists two veterinary officers and a livestock officer.

SOMALIA

ISNAR 1986 (Pardey and Roseboom 1989): 2 PhD, 10 MSc, 24 BSc = 35

Agricultural Research Institute (ARI) of the Ministry of Agriculture.

Livestock and range research is not undertaken by ARI, but by the Department of Animal Health, the Department of Animal Production, the Trypanosomiasis Control Project, and the National Range Agency.

SOUTH AFRICA

ISNAR 1985 (Pardey and Roseboom 1989): 1647 researchers, including 162 PhD, 197 MSc and 316 BSc within the Department of Agriculture and Water Supply. This included 24 PhD, 30 MSc and 50 BSc (=104) in the Animal and Dairy Science Research Institutes, and 19 PhD, 13 MSc and 52 BSc (=84) in the Veterinary Institute. Total researchers include the Council for Scientific and Industrial Research, with its National Food Research Institute, and the South African Wool and Textile Research Institute, and the Faculties of Agriculture and Veterinary Science, the latter with 58 PhD, 30 MSc and 36 BSc (=124).

Under the post-apartheid government, research is being re-directed towards meeting the needs of communal rather than commercial (i.e. white) farmers (White and O'Meagher 1997).

ISNAR 1992 (Roseboom et al. 1995b):

Under the Agricultural Research Council there is the Onderstepoort Veterinary Institute with 78.0 FTEs, and the Irene Animal Production Institute with 94.0 FTEs.

There are a number of Agricultural Development Institutes under the Department of Agriculture (Dohne, Glen, Potchefstroom, Grootfontein, Cedara, Transvaal, and Elsenburg — e.g. refer White and O'Meagher 1997) that focus on crops, livestock and natural resources. These have 188 FTEs.

The Universities of Stellenbosch, Pretoria, Natal, North, Orange Free State, Fort Hare, Bophuthatswana, Zululand and Venda have Faculties or Schools of Agriculture. The University of Pretoria and the Medical University of South Africa have Faculties of Veterinary Science.

There is an economically active agricultural population of 1.8 million (probably conservative— White and O'Meagher 1997), with 746 researchers per million.

Research expenditure is 3.68 % of Ag GDP. 426.4 PhD, 493.3 MSc, 519.8 BSc = 1439.5

Livestock research accounts for 26.3 % of the total, with 367.1 FTEs.

FAO/OIE/WHO 1995:

Total veterinarians	2156
.. in labs, universities, etc.	238
Total animal health aux.	1682

UNESCO Education indicators 1995:

Third level of education	17.3%
Education \$s as % of GNP	6.8
Education \$s as % gov't spending	20.5

SRI LANKA

Numerous agricultural research institutes related to many different ministries.

Agricultural Research and Training Institute (ARTI)

Department of Animal Production and Health (DAPH)

Department of Agriculture (DOA)

Ministry of Agricultural Development and Research (MADR)

Ministry of Rural Industrial Development (MRID)

Veterinary Research Institute (VRI) ..

Peradeniya.

ISNAR 1983 (Pardey and Roseboom 1989): 67 PhD, 116 MSc, 208 BSc = 391

CABI 1989: The Department of Animal Production and Health, based at Peradeniya, has 18 graduates, including 2 on poultry pathology and 2 on monogastric nutrition. The University of Peradeniya has 6 in its Department of Animal Science (mostly nutritionists), and the University of Ruhuna has 4.

FAO/OIE/WHO 1995:

Total veterinarians	485
.. in labs, universities, etc.	60
Total animal health aux.	650

UNESCO Education indicators 1995:	
Third level of education	5.1%
Education \$s as % of GNP	3.1
Education \$s as % gov't spending	8.2

SUDAN

ISNAR 1986 (Pardey and Roseboom 1989): 129 PhD, 68 MSc, 51 BSc = 248

Agricultural Research Corporation; figures exclude Animal Production Research Administration (29 researchers in 1977) and the Veterinary Research Administration (69 researchers in 1983).

ISNAR 1991 (Beintema et al. 1994c): Ministry of Agriculture, Natural Resources and Animal Health—the Agricultural Research Corporation (includes livestock) has 32 sites, 218 national researchers (218.0 FTEs), the Animal Production Research Administration has 5 research sites with 31 national researchers (31.0 FTEs) and the Veterinary Research Laboratories Administration has 137 national researchers (137.0 FTEs).

The Faculty of Veterinary Medicine at the University of Khartoum has 55 national researchers (16.5 FTEs).

Economically active agricultural population of 5.0 million, with 85.4 researchers per million

Research expenditure equals 0.41% of Ag GDP.

217.9 PhD, 147.4 MSc, 59.0 BSc = 424.3 + 0.1 Expats.

Livestock accounts for 35.5 % of total research and 150.5 FTEs.

FAO/OIE/WHO 1995:

Total veterinarians	3688
.. in labs, universities, etc.	700
Total animal health aux.	1193

UNESCO Education indicators 1995:

Third level of education	4.0%
Education \$s as % of GNP	—
Education \$s as % gov't spending	—

SWAZILAND

ISNAR 1983 (Pardey and Roseboom 1989): 2 MSc, 10 BSc = 12 + 6 Expats in the Agricultural Research Division of the Ministry of Agriculture and Cooperatives. Malkerns Research Station.

ISNAR 1992 (Beintema et al. 1995d): The Agricultural Research Division of the Ministry of Agriculture and Cooperatives had 2 staffed research sites with 12 national researchers and 2 Expats = 14.0 FTEs
The Faculty of Agriculture in the University of Swaziland had 38 nationals and 19 Expats = 5.7 FTEs

Economically active agricultural population of 214,000 with 88.4 researchers per million
Research expenditure is 2.44% of Ag GDP
3.8 PhD, 10.0 MSc and 2.0 BSc = 15.8 + 2.9 Expats = 18.7 FTEs

Livestock accounted for 8.0% of total research expenditure = 1.3 FTEs.

FAO/OIE/WHO 1995:

Total veterinarians	21
.. in labs, universities, etc.	2
Total animal health aux.	999

UNESCO Education indicators 1995:

Third level of education	6.0%
Education \$s as % of GNP	8.1
Education \$s as % gov't spending	—

SYRIAN ARAB REPUBLIC

ISNAR 1983 (Pardey and Roseboom 1989): 24 PhD, 9 MSc, 217 BSc = 250 + 3 Expats

Scientific Agricultural Research Department of the Ministry of Agriculture and Agricultural Reform

TAIWAN

ISNAR 1985 (Pardey and Roseboom 1989): 262 PhD, 577 MSc, 1009 BSc = 1848

includes agricultural research institutes, universities and agribusiness

TANZANIA

Tanzania Agricultural Research Organisation (TARO)—mainly crop research

Tanzania Livestock Research Organisation (TALIRO)

Uyole Agricultural Center (UAC)

ISNAR 1984 (Pardey and Roseboom 1989): 19 PhD, 98 MSc and 120 BSc = 237 + 68 Expats; 56 researchers in TALIRO in 1984.

CABI 1989:

TALIRO has 58 graduates (mostly veterinary and animal science), with livestock research centres at Mpwapwa, West Kilimanjaro, Tanga, Malya and Kongwa (pasture research).

FAO/OIE/WHO 1995:

Total veterinarians	465
.. in labs, universities, etc.	60
Total animal health aux.	4940

THAILAND

Kasetsart Agricultural University

UNESCO Education indicators 1995:

Third level of education	20.1%
Education \$s as % of GNP	4.2
Education \$s as % gov't spending	20.1

TOGO

ISNAR 1986 (Pardey and Roseboom 1989): 44 national researchers and 14 Expats.

ISNAR 1991 (Beintema et al. 1996): Institut National Zootechniques and Vétérinaire had 6.0 FTEs working on animal health and production. At the Université du Bénin en Togo (food crops, livestock, natural resources) there were 25 national researchers and 1 expat = 1.3 FTEs. Economically active agricultural population of 1.0 million, with 85.9 researchers per million.

Research expenditure is 0.96 % of Ag GDP. 11.2 PhD, 42.5 MSc, 20.6 BSc = 74.3 plus 12.9 Expats = 87.1

Livestock research accounts for 7.1 % of total research, or 6.2 FTEs.

UNESCO Education indicators 1995:

Third level of education	3.5%
Education \$s as % of GNP	5.6
Education \$s as % gov't spending	18.7

TONGA

ISNAR 1986 (Pardey and Roseboom 1989): 3 MSc, 6 PhD = 9 + 12 Expats in the Research Division of the Ministry of Agriculture, Fisheries and Forests.

UGANDA

ISNAR 1982 (Pardey and Roseboom 1989): 185 researchers includes Department of Veterinary Services and Animal Industry, and the Faculty of Agriculture and Forestry at Makerere University

CABI 1989:

The Ministry of Agriculture and Forestry has 3 livestock specialists and 2 pasture specialists at the Namulonga Research Station.

FAO/OIE/WHO 1995:

Total veterinarians	557
.. in labs, universities, etc.	91
Total animal health aux.	381

UNESCO Education indicators 1995:

Third level of education	1.7%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

URUGUAY

ISNAR 1985 (Pardey and Roseboom 1989): 18 MSc and 51 BSc = 69

Centro de Investigaciones Agrícolas “Alberto Boerger” (CIAAB)

Excludes Centro de Investigaciones Veterinarias “Miguel C. Rubino” (36 researchers) and the Facultad de Medicina Veterinaria.

FAO/OIE/WHO 1995:

Total veterinarians	2600
.. in labs, universities, etc.	275
Total animal health aux.	550

UNESCO Education indicators 1995:

Third level of education	28.4%
Education \$s as % of GNP	2.8
Education \$s as % gov't spending	–

VANUATU

ISNAR 1985 (Pardey and Roseboom 1989): 0 BSc + 12 Expats in the Institut de Recherches pour les Huiles et les Oleagineux (IRHO).

FAO/OIE/WHO 1995:

Total veterinarians	6
.. in labs, universities, etc.	0
Total animal health aux.	18

UNESCO Education indicators 1995:

Third level of education	–
Education \$s as % of GNP	4.9
Education \$s as % gov't spending	–

VENEZUELA

ISNAR 1983 (Pardey and Roseboom 1989): 18 PhD, 135 MSc, 230 BSc = 383

Fondo Nacional de Investigaciones Agropecuarias (FONAIAP)

FAO/OIE/WHO 1995:

Total veterinarians	5150
.. in labs, universities, etc.	1050
Total animal health aux.	1130

UNESCO Education indicators 1995:

Third level of education	26.0%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

VIETNAM**FAO/OIE/WHO 1995:**

Total veterinarians	3535
.. in labs, universities, etc.	370
Total animal health aux.	4350

UNESCO Education indicators 1995:

Third level of education	4.1%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–

WESTERN SAMOA

ISNAR 1986 (Pardey and Roseboom 1989): 2 MSc, 3 BSc = 5 + 5 Expats—researchers at the Western Samoan Ministry of Agriculture.

YEMEN ARAB REPUBLIC

ISNAR 1986 (Pardey and Roseboom 1989): 11 PhD, 24 MSc, 30 BSc = 65 + 11 Expats.

Agricultural Research Authority within the Ministry of Agriculture and Fisheries

ZAIRE

ISNAR 1983 (Pardey and Roseboom 1989): 2 PhD, 8 MSc, 33 BSc = 43

Institut National pour l'Etude et la Recherche Agronomique (INERA)

Laboratoire Vétérinaire de Kinshasa (LVK)

Centre de Recherche au Sciences Naturelle (CRSN)

ZAMBIA

ISNAR 1986 (Pardey and Roseboom 1989): 4 PhD, 24 MSc, 57 BSc = 85 + 68 Expats

The main agricultural research organisation is the Research Branch of the Department of Agriculture within the Ministry of Agriculture and Water Development. Also the Department of Veterinary and Tsetse Control.

ISNAR 1992 (Roseboom and Pardey 1995): MAFF—Department of Agriculture—the Research Branch (crops and livestock) has 16 staffed research sites with 138 national researchers and 16 Expats = 164.0 FTEs. The Central Veterinary Research Institute has 6 sites with 10 national researchers and 1 Expat = 11.0 FTEs.

The Livestock and Pest Research Centre (MHEST—National Council for Scientific Research) has 11.0 FTEs (national researchers).

The University of Zambia has a School of Agricultural Sciences with 26 national researchers and 6 Expats (8.0 FTEs) and a School of Veterinary Medicine with 21 national researchers and 20 Expats = 16.4 FTEs.

Economically active agricultural population of 1.98 million, with 134.9 researchers per million.

Research expenditure is 1.31 % of AgGDP.

Livestock research accounts for 20.8 % of total research, or 55.7 FTEs

CABI 1989: lists only an animal husbandry research officer at the Mongu Regional Research Station.

FAO/OIE/WHO 1995:

Total veterinarians	148
.. in labs, universities, etc.	37
Total animal health aux.	684

UNESCO Education indicators 1995:

Third level of education	2.5%
Education \$s as % of GNP	1.8
Education \$s as % gov't spending	–

ZIMBABWE

ISNAR 1983 (Pardey and Roseboom 1989):
16 PhD, 51 MSc and 84 BSc = 151,
increased to a total of 193 in 1985.

This includes the Ministry of Agriculture,
the Tobacco Research Board, and the Pig
Industry Board. The Department of
Veterinary Services is also involved in
agricultural research.

Funding by the Zimbabwe Agricultural
Research Council.

Explicitly not included are universities and
international agricultural research institutes.

ISNAR 1992 (Roseboom et al. 1995a):
Ministry of Lands, Agriculture and Water
Development has a Department of Research
and Specialist Services with 15 staffed
research sites with 117 national researchers
and 10 Expats = 127.0 FTEs. The Ministry
also has a Veterinary Research Laboratory
with 9.0 FTEs and a Tsetse and
Trypanosomiasis Control Branch with 3.0
FTEs.

There is a Pig Industry Board with 2.0 FTEs
at an experimental farm.

The University of Zimbabwe, with Faculties
of Agriculture and Veterinary Science, has
295 national researchers and 38 Expats =
254.2 FTEs.

Economically active agricultural population
of 2.8 million, with 91.7 researchers per
million.

Research expenditure is 1.55 % of Ag GDP.

40.0 PhD, 79.5 MSc, 128.5 BSc = 248.0
FTEs + 38.0 Expats = 286.0 FTEs

Livestock research accounts for 21.8 % of
total research = 55.4 FTEs

CABI 1989: Ministry of Lands, Agriculture
and Rural Resettlement has 9 graduates in
Dairy Services at Harare, 6 in livestock and
pasture at the Grasslands Research Station
at Marondera, and 9 at the Henderson
Research Station (livestock, including dairy
and poultry, and pastures). The Matapos
Research Station at Bulawayo has 11
graduates, with emphasis on range livestock
nutrition, veld management and ecology, 8
on livestock nutrition and breeding, and 2 on
small ruminants. There are 16 in the
Department of Veterinary Services and 2 at
the Pig Industry Board Experimental Farm.
There are 4 specialists in animal nutrition
and animal production systems at the
University of Zimbabwe.

FAO/OIE/WHO 1995:

Total veterinarians	234
.. in labs, universities, etc.	30
Total animal health aux.	817

UNESCO Education indicators 1995:

Third level of education	6.9%
Education \$s as % of GNP	–
Education \$s as % gov't spending	–