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A GLOBAL AGRO-CLIMATIC ANALYSIS OF THE DISTRIBUTION AND PRODUCTION OF LIVESTOCK COMMODITIES

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Acronyms and Abbreviations

ACIAR	Australian Centre for International Agricultural Research
AGA	Animal Production and Health Division of the FAO
AGL	Land and Water Development Division of the FAO
AEZ	Agro-ecological zone
ASIT	Agro-ecological Systems & Information Technology
ANU	Australian National University
AVHRR	Advanced Very High Resolution Radiometer
CGIAR	Consultative Group for International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical, Cali, Colombia.
CIS	Commonwealth of Independent States
CRES	Centre for Resource and Environmental Studies, ANU
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
DEM	Digital elevation model
ERGO	Environmental Research Group Oxford, U.K.
FAO	Food and Agricultural Organization of the United Nations
FEWS	Famine Early Warning System (FAO)
FTEs	Full-time equivalents
GIS	Geographic information system
GNP	Gross national product
IFPRI	International Food Policy Research Institute
IIASA	International Institute for Applied Systems Analysis, Vienna
ILRI	International Livestock Research Institute, Nairobi
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
LGP	Length of growing period
NARS	National Agricultural Research Systems
NASA	National Aeronautic and Space Administration, USA
NDVI	Normalised difference vegetation index
NOAA	National Oceanic and Atmospheric Administration, USA
OECD	Organization for Economic Cooperation and Development
OIE	Office International des Epizooties
PET	Potential evapotranspiration
SCARM	Standing Committee on Agriculture and Resource Management, Australia
SDRN	Environment and Natural Resources Service of FAO
SPAAR	Special Program for African Agricultural Research
TAC	Technical Advisory Committee of CGIAR
UCLA	University of California, Los Angeles
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
WAICENT	World Agricultural Information Centre
WHO	World Health Organization
www	World Wide Web

ABSTRACT

Investment in agricultural research in developing countries is being increasingly targeted at those areas and issues where the economic and environmental benefits may be expected to be greatest. However, this in turn requires more accurate estimates of these benefits, in that they are not confined to the immediate area where the research is carried out. In this study it is assumed that benefits are likely to be greater within the agro-climatic zone in which the research was carried out, though estimates are also required of expected technical spillovers, pre- and postharvest, to other agro-climatic zones. This first requires that the zones themselves be defined, along with information on the size and commodity output of livestock industries within agro-climatic zones in different countries. The capacity for undertaking research, and adopting or adapting the results of research undertaken locally or in another country, also needs to be assessed.

Different methods for classifying agro-climatic zones were therefore compared. These included methods based on estimated length of growing period (LGP) using rainfall and temperature data, or the ratio of precipitation to potential evapotranspiration, and on more detailed agronomic models. Remote sensing data and land use information are also being used to help define these zones.

The most appropriate classification method for ACIAR to use at this stage to aid research targeting and prioritisation at the country level would appear to be one based on six agro-climatic zones classified according to LGP. This is primarily because this zonation can be linked to existing livestock data. These zones are designated desert, arid, semi-arid, dry sub-humid, moist sub-humid and humid. However, within each zone it is possible for further subdivision according to the dominant livestock production systems, namely grassland-based, rainfed mixed farming and irrigated mixed farming.

Estimates of livestock production have been constrained in the past because the data have been collected at the country level. However, by defining agro-climatic zones and relating concentrations of livestock populations to those of humans, it is now possible to make realistic estimates of livestock populations and the production of livestock commodities for most developing countries. Cattle density data collected at the subnational level in Africa by ILRI were also made available to this project. A series of 20 spreadsheets was prepared containing estimates of livestock numbers and productivity (meat, wool, milk, eggs) and manure production within different agro-climatic zones in each country. Supplementary spreadsheets containing details of land use in different countries were also prepared.

Quantitative estimates were made of preharvest and postharvest technology spillovers from one agro-climatic zone to another. The distinction was made between agronomic, animal health and animal production technologies with ruminants, and between health and production with pigs and poultry. Postharvest technology spillovers tended to be more independent of agro-climatic zone, so that technology benefits could flow more easily between zones. Perishable livestock products presented greater challenges in terms of

technology spillovers between climatically dissimilar zones than relatively enduring products such as wool.

Estimates were made of the basic and adaptive research capability to assist agriculture in 50 countries and regions, particularly focusing on Asia and Africa. This included summarising details on agricultural research, animal health services, and expenditure on education in most countries around the world.

RECOMMENDATIONS

- That there be increased emphasis on defining agro-climatic and agro-ecological zones throughout the developing countries in which ACIAR commissions research. This would assist in focusing the efforts of research teams on particular issues and problems, and in estimating the likely benefits of research, thereby contributing to improved prioritisation of research programs. Attention needs to be given to the purpose of the zonation, which will often be related to increasing population and socioeconomic issues, to the capacity for future increases in production and productivity, and to environmental concerns about land degradation and other threats to the natural resource base.
- That it be recognised that agro-climatic and agro-ecological zone (AEZ) definition can be facilitated considerably through the use of digital elevation models, climate surfaces, plant growth models such as GROWEST (Nix 1981; Zuo 1996), field and remote sensing data, and geographic information systems. There are several resource issues (staffing, subcontracting, hardware, software) for ACIAR to consider here.
- That the most pragmatic approach for relating livestock density and commodities data to agro-climatic zones is to define these zones on the basis of length of growing season, there being six zones designated as desert, arid, semi-arid, dry sub-humid, moist sub-humid and humid. This classification was used in this study, and is consistent with current work being undertaken by FAO and ERGO (FAO 1996a, 1996b; Slingenbergh and Wint 1997).
- That there be provision for these zones to be further subdivided in future as additional data and computing resources become available. Sixteen zones based on length of growing period have already been identified, but that there should also be provision for further zonation based on land use (pastoral versus dryland mixed farming versus irrigated mixed farming), and for extra discrimination based on the use of agronomic models, remote sensing data, and socio-economic data within a geographic information system (GIS).
- That ACIAR consider providing resources to expedite the publication of the digital elevation model, climate surfaces and agro-ecological zones for mainland East Asia (Zuo 1996) on CD-ROM, including further analysis to determine the actual areas in each country taken up by each AEZ. This work has been funded in part by ACIAR.
- That ACIAR consider a collaborative program involving FAO, ERGO, ILRI, CRES and possibly ASIT Consulting to obtain crop and livestock coverages and land utilisation patterns throughout developing countries with which it is involved. This would help research targeting and prioritisation, and the planning, implementation and evaluation of its research programs. It would also provide the required GIS linkage to overlay the data within a higher resolution of agro-climatic zones, as these become defined.

  ILRI has a global mandate to extend its crop and livestock coverages from Africa to other parts of the world, and is specifically interested in doing so in Asia. AGA, within FAO, has as its goal to relate livestock land utilisation patterns at the national and sub-national level to food and income security and sustainable development. ERGO has been assisting FAO by developing techniques to predict cattle and cultivation levels *within AEZs of countries around the world. CRES has been undertaking agro-ecological analyses of mainland East Asia and Sri Lanka.*

- That ACIAR undertake selected case studies, in consultation with its overseas partners and collaborators, to test a sample of the pre- and postharvest technology transfer and research capacity coefficients estimated during this study.

INTRODUCTION

This project was undertaken to develop a livestock commodities database for use in refining ACIAR's regional commodities priorities table. This is to help ACIAR in its efforts to improve the allocation of research resources to aid livestock production within developing countries (Davis and Lubulwa 1995).

TASK 1. REFINE THE AGRO-CLIMATIC ZONES APPROPRIATE FOR EACH COMMODITY

This included undertaking a feasibility study on this topic (White 1998).

Objectives of task 1

To determine the feasibility, value and limitations of different approaches that can be used, either alone or in combination, to refine agro-climatic zones for different livestock commodities.

To identify where the problems of classification and interpretation are likely to arise.

Definitions

The following definitions are used by Australia's SCARM (Standing Committee on Agriculture and Resource Management) Working Group on Sustainable Agriculture:

Agro-climatic regions

This term is used to denote regions with a characteristic inter-relationship between agronomy/farming systems and climate.

Agro-ecological regions

Similarly, agro-ecological regions are those with a characteristic inter-relationship between agronomy/farming systems and various environmental features, not just climate.

Agro-ecosystems

An agro-ecosystem has been defined as an ecosystem manipulated by frequent, marked anthropogenic modifications of its biotic and abiotic environments (Coleman and Hendrix 1988). Four main types of modification have been recognised. These are, briefly: inputs of energy; reduction in biotic diversity so as to maximise yield of economic products; artificial selection; and external control which is goal-orientated (Odum 1969).

Agro-climatic and agro-ecological regions

Agro-climatic and agro-ecological zonation schemes are standard tools used to target agricultural research and to set research priorities because they provide information about target environments (Corbett 1996). Indeed, this is the major reason for this study. A proper description of the target environment also enables research efforts to be more clearly focused at local issues and needs.

Ways in which these zones are characterised are changing as the reproducibility and flexibility of geographical information systems (GIS) loosen the former restrictions to data integration.

Agro-climatic and agro-ecological GIS have created a new environment to conduct similar research prioritisation and targeting efforts. With GIS, one can greatly refine the methodologies by which ‘targets’ are defined, while at the same time expanding the opportunities and potential for the accurate targeting of agricultural research efforts.

An accurate spatial (and temporal) database enables the characterisation of agro-ecosystems. This ability is vital in the developing world for efficient resource allocation in agricultural research. Agro-ecosystems are complex entities that span several levels or scales, with different processes dominating each scale. Therefore, a dynamic agro-ecosystem characterisation requires both biophysical and socioeconomic data. Characterisation integrity is maintained by addressing particular objectives with specific information, information which may not aggregate with scaling up or down (e.g. the aggregate description of a complex of soils would not deliver a sensible ‘regional’ characterisation).

With spatially interpolated climate data, digital elevation models, and low resolution soils data in place, agro-ecosystem characterisation commences with simple models used to differentiate growing season and off season characteristics. These ‘climate analog’ models serve to describe the initial domain or target area for a range of priority setting steps, from sample design in diagnostic surveys and field trials to the identification of constraints and the number of people affected for institutional priority setting. Socioeconomic information—usually much more difficult to acquire—becomes critical in refining target domains as resource access, land tenure, cropping system, labour availability and so on dominate the land use system at higher resolutions.

Methodology for refining agro-climatic zones

The task of refining agro-climatic zones involved the following:

1. comparing approaches used by different institutions;
2. examining FAO and other livestock population and land-use data, these showing the outcome of a range of biophysical and socioeconomic factors influencing rural production systems;
3. examining climate systems in different parts of the world, and identifying the dominant soils, topography and vegetation;
4. using human population density rather than climate data as the major determinant of livestock population density; and
5. assessing how remote sensing data are being used to monitor vegetation, agro-climatic data and land use around the world.

Major data sources were areas of the different agro-ecological zones within countries, based on agro-ecosystems being subdivided into either 6 or 16 zones according to the estimated length of growing period. Total livestock weight, and livestock weights for individual species, were provided for each of the six zones by Dr William Wint (ERGO) and Dr Jan Slingenbergh (FAO). This information was critical to the success of this project.

ARC/INFO information on cattle distribution and AEZs for Africa was provided by Drs Phil Thornton and Russell Kruska of the International Livestock Research Institute (ILRI), Nairobi, Kenya, and mapped locally by Mr Shawn Laffan, Department of Geography, Australian National University. AEZs used at ILRI were based on length of growing period. The cattle density data provided a check on the model-based estimates.

A comparison of different approaches to defining agro-climatic zones

The number of bioclimatic, agro-climatic, ecoclimatic and biogeographic classifications is very large (Le Houérou et al. 1993). Some are of general use while others are focused towards particular regions.

In choosing which classifications to evaluate and compare, attention was directed to those that have been in or are coming into common use. It was considered appropriate to pay particular attention to the preferred systems used by the Food and Agriculture Organization of the United Nations (FAO), the Consultative Group for International Agricultural Research (CGIAR) including its Technical Advisory Committee (TAC), and the Environmental Research Group Oxford (ERGO) which has been undertaking GIS-based consultancy work for FAO. Other organisations approached included the International Livestock Research Institute (ILRI), CIAT, the Centre for Resource and Environmental Studies (CRES) at the Australian National University, and the CSIRO Division of Forestry and Forest Products.

Köppen climate classification system

Until recently the most widely used system of climate classification has been that of the German climatologist Köppen (1936)—many later classifications are variants of the 'Köppen (or Koeppen) system' (FAO). The classification is based on monthly rainfall and temperatures, including the following five inputs:

- Average temperature of the warmest month
- Average monthly temperature of the coldest month
- Average thermal amplitude between the coldest and warmest months
- Number of months with temperature exceeding 10°C
- Winter and summer rains.

The global map (Figure 1) shows the location and extent of the individual regions. This may also be viewed or downloaded from the FAO WWW site:

< http://www.fao.org/WAICENT/FAOINFO/sustdev/EIdirect/Climate/EIsp0054.htm >

In summary, the Köppen system is a static, empirically based descriptive system that was appropriate for the pre-computer era.

Agro-climatic determination of agro-ecological zones (FAO 1978–81)

Probably the first serious attempt to use computers to help integrate climate, soil and plant information in order to determine agro-ecological zones throughout the world was that reported by FAO (1978–81).

Agro-ecological zones were determined by overlaying climatic inventories for different sites on soils maps, soil characteristics in terms of slope, texture and phase being used to provide an assessment of land suitability for different crops. Crop yields were estimated on the basis of crop phenology and yield potential, with reduction factors in terms of crop yield loss due to water stress, pests, weeds and diseases, and constraints in terms of the 'workability' of the soil.

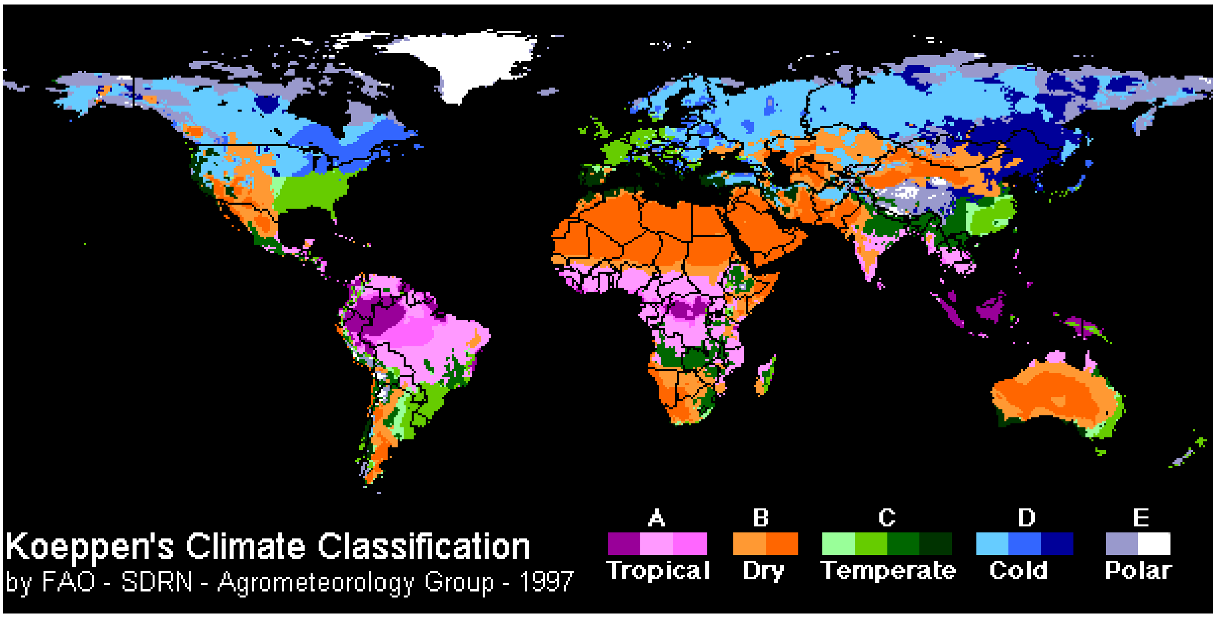

Figure 1. **Köppen climate classification system**

Climate data were used to estimate the length of the growing period (LGP), the time available when water and temperature permit growth, based on estimates of soil water balance. For a crop to be growing it was assumed that rainfall had to at least equal 50% of potential evapotranspiration (PET) for crop growth to be achieved, and that the mean daily temperature during the growing period had to exceed 5°C. The distinction was made between the humid and non-humid parts of the year, according to when precipitation exceeded PET. Subsequent developments of the LGP concept are reported on in subsequent sections of this report.

Agro-bioclimatic classification of Africa (Le Houérou et al. 1993)

Le Houérou et al. (1993) rejected the Köppen (1936) and similar classifications. This was because they were based on the 'empirical and somewhat obsolete, albeit fairly efficient, relationship between precipitation and temperature as a criterion of water stress/water availability and on mean annual temperature as a criterion of cold or heat stress, which lacks accuracy, sensitivity and efficiency'.

Le Houérou and colleagues tried to identify simple, rational and reliable parameters to represent water and temperature requirements and constraints. The discriminating values of these parameters were selected on the basis of agronomic and ecological criteria of the distribution of native vegetation, wildlife, crops and livestock, in an attempt to make this classification realistic and useable for the continent as a whole, with the aim of producing a framework that could be safely used by agronomists, land managers and planners.

Their classification combined a rather large number of climatic, biological, agronomic and geographic criteria. The actual number of combinations is about 200. Some of these occupy very large areas, such as the hyper-humid equatorial lowlands (some 9 million km^2), or the extra-tropical, winter rainfall, cold hyper-arid lands (some 5 million km^2), whereas other combinations, such as the afro-alpine and mediterraneo-alpine ecozones and the equatorial hyper-arid midland ecozone, cover very small areas

The large number of categories in this classification system is clearly impractical for use in the current ACIAR project aimed at estimating the benefits to agricultural research within and between regions and countries. Furthermore, to use this classification would clearly require a digitised dataset containing the boundaries and details of the wide range of agro-ecosystems. Also, to develop an equivalent system in say Asia or South America would require considerable resources.

Climate classification based on potential crop production (Hutchinson et al. 1992)

This classification of the world's climates is based on monthly climate data from around the world. In addition to the mean and seasonality attributes for rainfall and two attributes based on temperature extremes, the attributes are based on successive 13-week accumulated values of indices calculated by the GROWEST crop growth model (Fitzpatrick and Nix 1970; Nix 1981) for each week of the year for mesotherm plants (temperature optimum = 19ºC) and megatherms (temperature optimum = 28°C). Thirteen standard weeks corresponds to the growing period for the earliest-maturing grain crops grown in very favourable climates, and also provides a measure of the most important period for growth of later maturing and perennial crops. The broadest groupings were based on temperature except for the warm/hot and very dry (desert) climates. This parallels the principal Köppen divisions. The next divisions were principally based on moisture, giving rise to 10 broad groups.

This method was used to classify climates in Africa (Hutchinson et al. 1996). It has since been applied in mainland East Asia by Zuo (1996)and Zuo et al. (1996a,b) to produce a classification and maps of agro-climatic zones throughout the region (Figure 2). A similar classification has been done for Sri Lanka (Kannangara 1998). Zone definition is probably the best of all the available systems. However, no information has been published on area of these zones. One would also have to overlay spatial estimates of livestock distribution on these zones within a GIS to more accurately fulfil the objectives of this study.

Prerequisites of the system include a digital elevation model (DEM) for the area in question, and an adequate density of climate stations. Also needed are software and staff familiar with the models and the Unix platforms no which they run.

Until recently a great deal of digitisation has been required to construct a DEM. However, the American Defence Mapping Agency has recently published a CD-ROM database of the Digital Chart of the World (DCW). This contains all of the information on maps of Operational Navigation Charts (ONC) series throughout the world at a scale of 1:1 million. Digital terrain data can be extracted from this database with ARC/INFO programs.

Climatic mapping programs, such as WORLD (Booth 1990) and GREEN (Hong et al. 1996), have been developed by CSIRO and its collaborators with support from ACIAR and AusAID for several different countries including Australia, Indonesia, Laos, Vietnam, the Philippines, Thailand and Zimbabwe, as well as for major regions such as Africa and Latin America. Emphasis has been on determining appropriate provenances of Australian tree species.

Agro-climatic classification for Mainland East Asia (Zuo 1996; Zuo et al. 1996a,b)

Mainland East Asia, as classified by Zuo (1996), includes China, Vietnam, Laos, Thailand, Kampuchea and Peninsular Malaysia. These are some of the most densely populated areas in the world. With more than one fifth of the world's population living on less than one tenth of the world's land, in areas mostly covered by high mountains, plateaux and deserts, the resource deficiencies are obvious and very serious.

A GIS-based agro-climatic classification was developed for mainland East Asia in this study, based on regular grid data sets at a resolution of 1/20th degree and agro-climatic indices simulated by GROWEST a general plant growth model (Nix 1981). The climatic data sets were developed using climatic surfaces interpolated by ANUSPLIN (Hutchinson 1984, 1991) and a digital elevation model (DEM) calculated using ANUDEM (Hutchinson 1989a,b). The classification attributes were all those simulated using the GROWEST model at a weekly step for each of the grid cells across mainland East Asia. Thirty-nine GROWEST attributes were selected as classificatory variables for each grid cell. Finally 14 agro-climatic zones were developed using PATN, a numerical taxonomy package (Belbin 1987). Each agro-climatic zone represents a particular cropping system or vegetation pattern (Figure 2).

Each agro-climatic zone represents a typical cropping system or vegetation pattern.

Agro-climatic Zone I– the high cold plateau climate of west China;

Agro-climatic Zone II– the dry and hot desert areas in northwest China;

Agro-climatic Zone III– the grazing grasslands of north and west China;

Agro-climatic Zone IV– the single temperate crop area in northeast China;

Agro-climatic Zone V– wheat-dominated double cropping system of north China plain;

Agro-climatic Zone VI– rice-dominated double cropping system in the south of Yangtze;

Agro-climatic Zone VII– the sub-alpine forest area of southern China;

Agro-climatic Zone VIII– the warm highlands of southwest China;

Agro-climatic Zone IX– mountain tops of humid tropical areas of China, Southeast Asia;

Agro-climatic Zone X– the humid tropical highlands;

Agro-climatic Zone XI– triple cropping systems—southern China, northern Vietnam;

Agro-climatic Zone XII– humid tropical lowlands of Southeast Asia;

Agro-climatic Zone XIII– wet tropical highlands of equatorial area; and

Agro-climatic Zone XIV– wet tropical lowlands of equatorial areas.

Although this classification agrees with the main features of previous agro-climatic classifications, differences are evident because of the different philosophy and methodology adopted in this study. The most significant difference occurs in the areas between the Huai River and the Yangtze River. Analyses of this study indicated that the climatic environment of the area is more closely related to the northern adjacent areas than to its southern neighbouring areas as noted in previous classifications (State Meteorological Administration of China 1978; Li 1993). More detail is provided by White (1998).

Revisions to the length-of-growing-period concept (Fischer et al. 1995)

The length-of-growing-period (LGP) has been defined as the period of the year in which agricultural production is possible from the viewpoint of moisture availability and suitable temperatures. The concept has been applied in many continental, regional and country-level studies as the basis for climatic inventories that were used, in combination with soils, terrain and crop information, to assess agricultural potentialities and constraints (e.g. FAO 1978–81; Nachtergaele and Bruggeman 1986). Most of these studies were located in tropical and subtropical areas where temperature constraints were, in general, of less importance than moisture availability in the position and properties of agricultural seasons. Given that the concept was originally developed as a regional water balance approach (Cochemé and Franquin 1967) for tropical areas it is not surprising that the application of the LGP-concept was most successful and extensive in these areas.

In temperate and cold areas temperature becomes more critical in determining the growing season. In addition, variations of day length, negligible at lower latitudes, become sufficiently important at higher latitudes to influence the agricultural productivity of particular seasons. At the same time, moisture constraints remain important determinants.

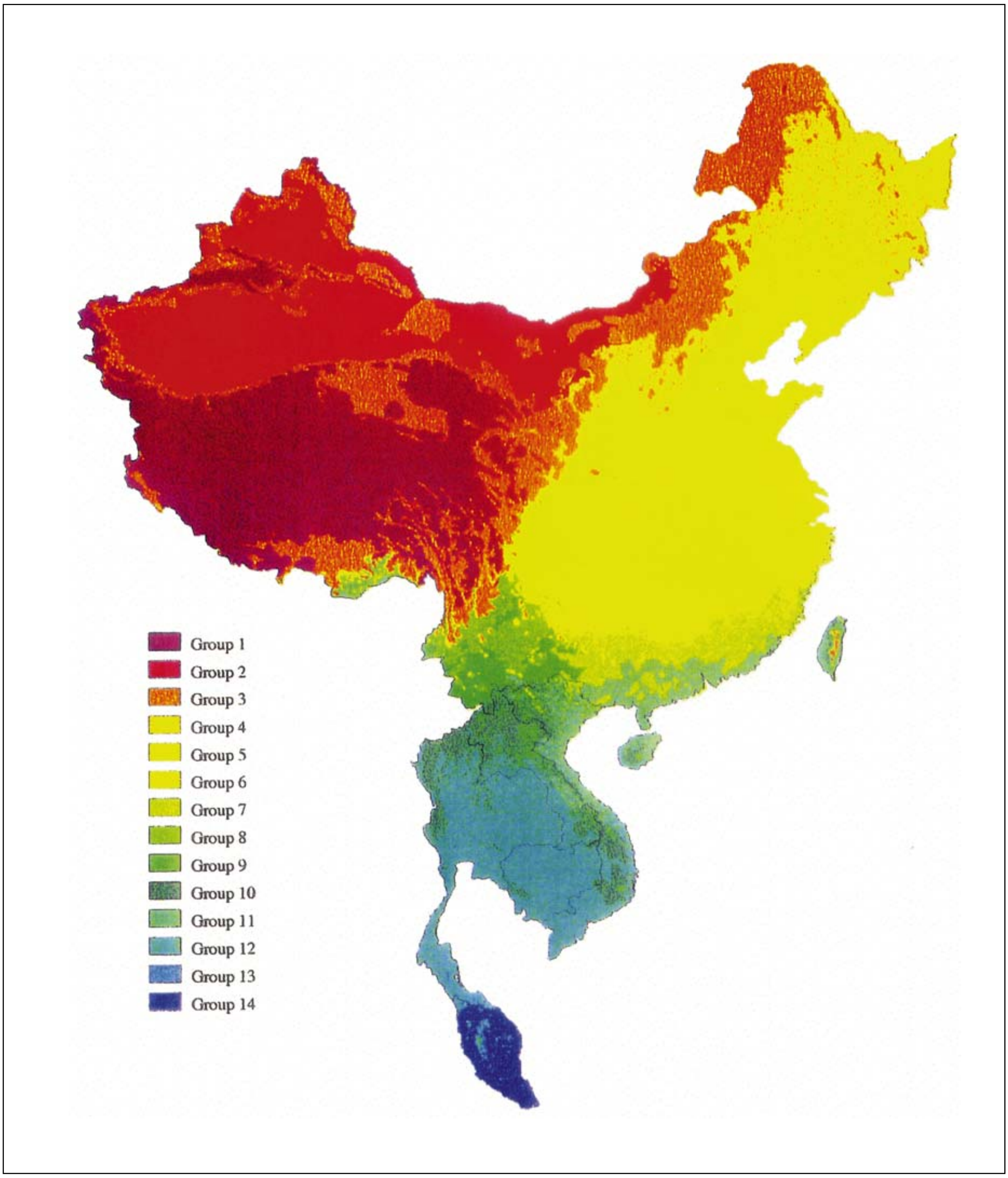

Figure 2. Agro-climatic zones of mainland East Asia (Zuo 1996)

The original LGP approach

In the original length-of-growing-period approach, the operational definition of growing period is (FAO, (1978-81):

> the period (in days) during the year when precipitation (P) exceeds half the potential evapotranspiration (PET) plus a period required to evapotranspire up to 100 mm of water from excess precipitation assumed stored in the soil profile.

The rationale for these operational limits is that they represent empirically validated thresholds for the reliable start and end of the agronomically relevant growing period, which take due account of early, unreliable rains and stored soil moisture, respectively. Different growing periods are recognised according to the portion of the year that rainfall exceeds potential evapotranspiration (humid versus dry) and average mean temperature exceeds 5°C.

To assess the quality of a growing period various types of growing periods were distinguished:

(i) A *normal growing period* contains a subperiod in which rainfall exceeds potential evapotranspiration (the ‘humid period’). The occurrence of a humid period within the growing period indicates that (a) the full evapotranspiration demands of rainfed upland crops at maximum canopy cover can be met, and (b) the moisture deficit of the soil is replenished.

(ii) An *intermediate growing period* is defined as a growing period that does not contain a humid subperiod. Within the intermediate growing period monthly rainfall is always below full but above half of monthly potential evapotranspiration. Under those conditions water availability does not meet the full water requirements of major food crops at maximum canopy cover.

(iii) An *all-year-round humid growing period* is a growing period in which the average monthly rainfall exceeds for every month of the year the average potential evapotranspiration.

(iv) An *all-year-round dry period* is characterised by an average monthly rainfall that does not exceed half the potential evapotranspiration for any month of the year.

It is clear that all these definitions and types are based on the moisture characteristics of growing periods. The temperature adequacy of a growing period is implied from the condition that no month can be part of a growing period unless its average mean temperature exceeds 5°C.

Temperature and moisture thresholds

A new approach to LGP-modelling proposed by Fischer et al. (1995) better integrates temperature- and moisture-related constraints, and makes the concept more suitable for a global climatic resources inventory. The temperature threshold for a growing period remains, as in the standard LGP approach, a mean temperature of 5°C, but the temperature and moisture-delimited growing period is defined through both water balance and temperature thresholds.

Water balance

A simple water balance approach was used in the original LGP model. The new approach treats moisture depletion rates as a function of moisture availability. Allowance is also made for the fact that in temperate and cold areas precipitation can be as snow. A third modification of the water balance relates to dormancy periods with temperatures above 0°C but below 5°C.

Zone classification based on length of growing period—Africa (Kruska et al. 1995)

As part of a program aimed at assembling livestock distribution coverages across Africa, Russ Kruska and Philip Thornton of ILRI kindly made available the ARC/INFO data sets on Africa for length of growing period (at two levels of aggregation) and cattle density distribution. These were plotted by Shawn Laffan of the Geography Department of the Australian National University, under sub-contract to ASIT Consulting (Figures 3 and 4). Figure 3 shows Africa subdivided into 14 zones based on 'normal days' of length of growing period, together with six zones based on the number of 'intermediate days', as described above (Fischer et al. 1995). Further detail is provided under Task 2 with respect to the cattle density distribution, which is presented in Figure 4 juxtaposed with a map where the distinction is made between only four zones (arid, semi-arid, sub-humid and humid).

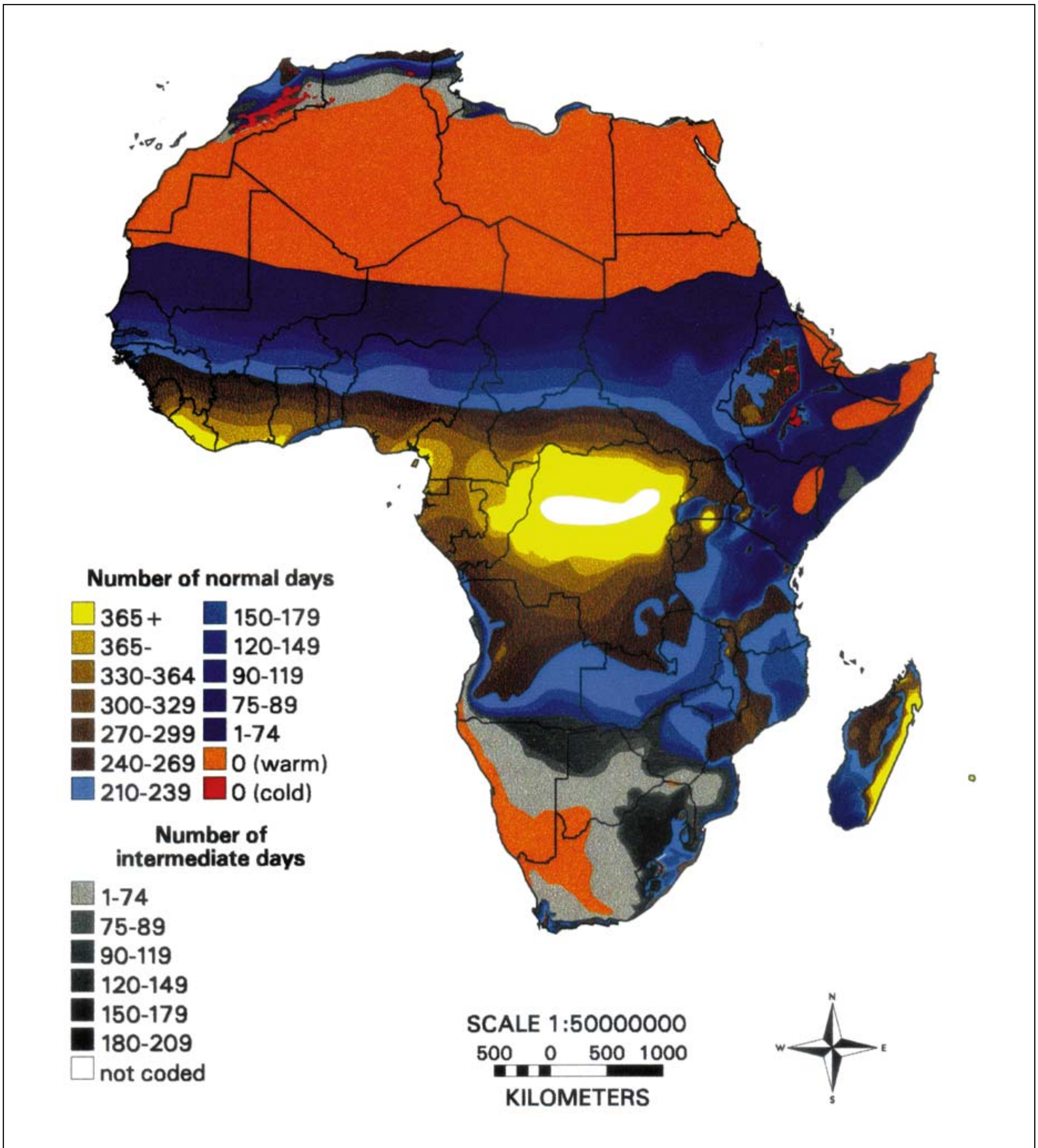

Figure 3. Length of growing period zones—Africa (ILRI)

Agro-ecological classification of Seré et al. (1996)

This classification is also based on the length of the growing period (LGP), which in this case is defined as the period (in days) during the year when rainfed available soil moisture supply is greater than half potential evapotranspiration (PET). It includes the period required to evapotranspire up to 100 mm of available soil moisture stored in the soil profile. It excludes any period with daily mean temperatures less than 5°C.

A major attraction of this approach is the relatively simple formula used to estimate the length of growing period, indicating that it could be relatively easy to compute provided global climatic data sets were available.

This approach started with the FAO/TAC LGP classification comprising 11 zones. For the purpose of a livestock system classification in which few clusters were sought, these were reduced to three: arid and semi-arid (< 180 growing days); humid and sub-humid (more than 180 growing days); and temperate and highland (temperature constraint). It is therefore a rather crude aggregation of the LGP concept. Three livestock production systems were considered: grazing systems; mixed rainfed systems; mixed irrigated; which equals 3 × 3 = 9 land-based systems. Two land-detached systems for monogastrics and ruminants were also included.

arid:	LGP less than 75 days
semi-arid:	LGP in the range 75–180 days
sub-humid:	LGP in the range 181–270 days
humid:	LGP greater than 270 days

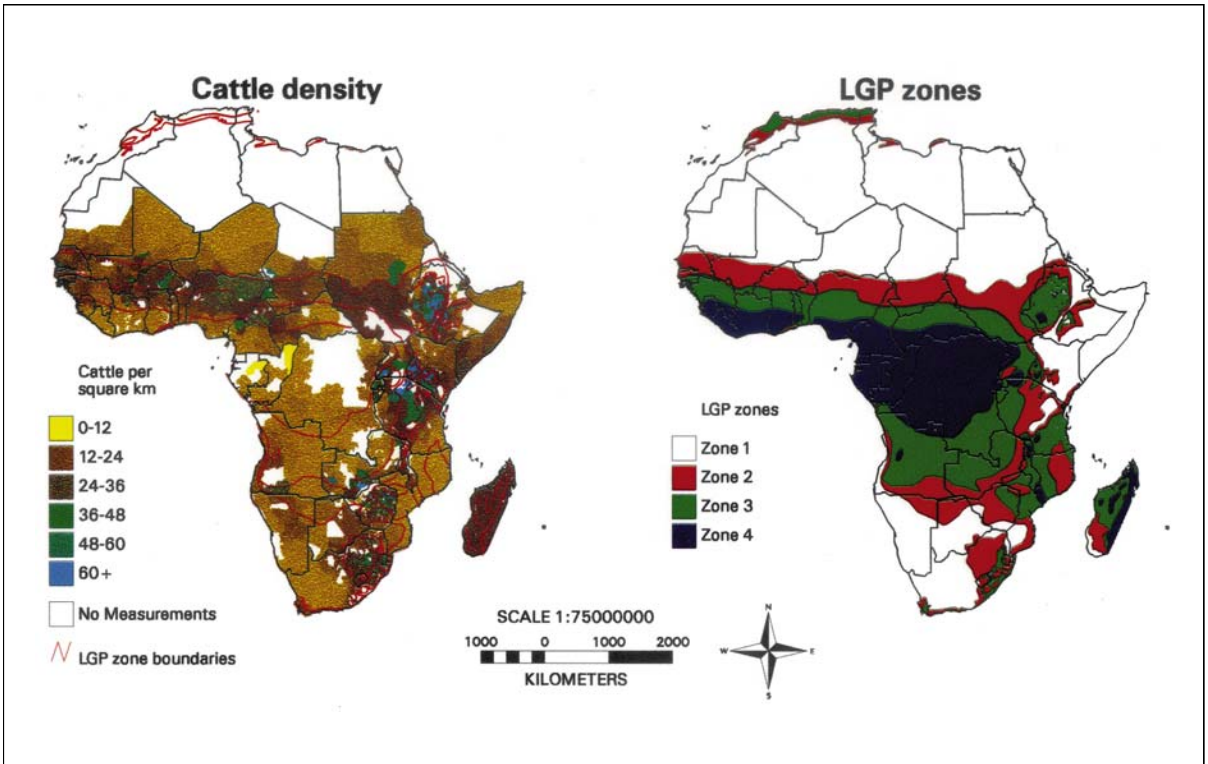

Figure 4. Cattle density distribution and LPG zones in Africa (ILRI)

Tropical highland areas and temperate regions are defined by their mean monthly temperatures. Temperate regions have one or more months with a monthly mean temperature, corrected to sea level, less than 5°C. Tropical highlands are tropical areas with daily mean temperature during the growing period in the range of 5–20°C.

This classification distinguishes between solely livestock systems, Grassland Based Systems, Rainfed Mixed Farming Systems, Irrigated Mixed Farming Systems, Landless Monogastric and Landless Ruminant Systems. Unfortunately, data distinguishing the number of livestock in irrigated and dryland systems could not be obtained for individual countries. In any case, the area of land that is irrigated is a small proportion of that available for agriculture, and in most countries is dominated by crops (Seré et al. 1996).

The study by Seré et al. (1996) contained estimates of land area, livestock numbers, livestock production and productivity indicators within each of the 11 agro-ecological systems for different regions of the world. These included: sub-Saharan Africa (SSA); Asia (ASIA); Central and South America (CSA); West Asia and North Africa (WANA); Organization for Economic Cooperation and Development (OECD) member countries, excluding Turkey which was included in WANA; eastern Europe and Commonwealth of Independent States (CIS); and other developed countries (Israel and South Africa) (ISA).

Ecozones, farming systems and length of growing period (Slingenbergh and Wint 1997)
Raster images for length of growing period (LGP) in 16 classes, national boundaries and human population level were available, initially for the African continent (FAO AGAH), and subsequently for the world (FAO AGL). Two primary outputs were required: vector maps of LGP zones (concatenated into 6 classes) within each Country; and population levels for each of these Zones.

The original 16 LGP zones were reclassified into six, and the resulting image comprised approximately 550 LGP zones by country (Figure 5).

The work of Wint and colleagues on African ecozones and farming systems is continuing (FAO 1997, 1998). Satellite data on land-surface and atmospheric characteristics are being used in the search for zonation criteria that are more ecologically based, including:

a) the Normalised Difference Vegetation Index (NDVI), commonly used as an indicator of vegetation cover;

b) a measure of ground surface temperature, derived from one of the thermal infra-red channels (channel 4; 10-day composite) on the NOAA satellite platform (AVHRR data; 1 km × 1 km resolution) by the NASA Global Inventory Monitoring and Modelling Systems (GIMMS) group; and

c) a measure of surface rainfall, the Cold Cloud Duration (CCD), derived from the METEOSAT satellite (8 km × 8 km resolution).

In addition, digital elevation model (DEM) data were obtained from a 0.083° resolution elevation surface for Africa, produced by the Global Land Information System (GLIS) of the United States Geological Survey, Earth Resources Observation Systems (USGS, EROS) data centre.

Farming systems in Kenya have corresponded quite closely with ecological zonations based on length of growing period (FAO 1998). Two sets of ecozones were identified, one with 11 zones, the other with 16. The major effect of increasing the number of zones was to split the drier areas into more categories. MANOVA analyses showed that 11 zones encompassed 77 and 46% of the variation in cattle and crops, respectively, as compared with 78 and 46% for the 16 zones.

Regression relationships were identified between remotely sensed surrogates for climate, human population, elevation, and known livestock and cropping distributions. These were used to predict livestock densities and cropping levels within a series of ecozones defined by unsupervised classification of the remotely sensed data. Elevation was found to be an important determinant of the ecozones, but as Hutchinson (1989a, 1991) has shown, that would primarily be through its impact on rainfall and temperature, the influence varying with latitude. For example, the most consistent predictors of cropping percentage in Kenya and Ethiopia appear to be human population number and elevation, as befits heavily populated areas concentrated in extensive highlands (FAO 1997). In Somalia, Sudan and Uganda, the predictors are more diverse, with rainfall and, to a lesser extent, vegetation cover being most frequent. Human population and elevation also predict cattle densities most often in Somalia, Sudan, Kenya and Ethiopia. Rainfall is also a frequent predictor, especially in Uganda and parts of Sudan. Cattle densities appear to be more closely related to population, especially in the more arid areas such as Mali and Chad, while elevation features predominantly in Niger. Elsewhere temperature or rainfall are more closely related to cattle numbers than are other eco-climatic variables.

Length of growing period relates closely to the satellite-derived ecozones (FAO 1998). The primary discriminating predictors were maximum temperature, minimum rainfall, mean NDVI and elevation, with the remainder being largely rainfall related. The AVHRR data were able to discern relatively slight variations within more arid areas, but were comparatively poor in discriminating between zones in the higher rainfall areas.

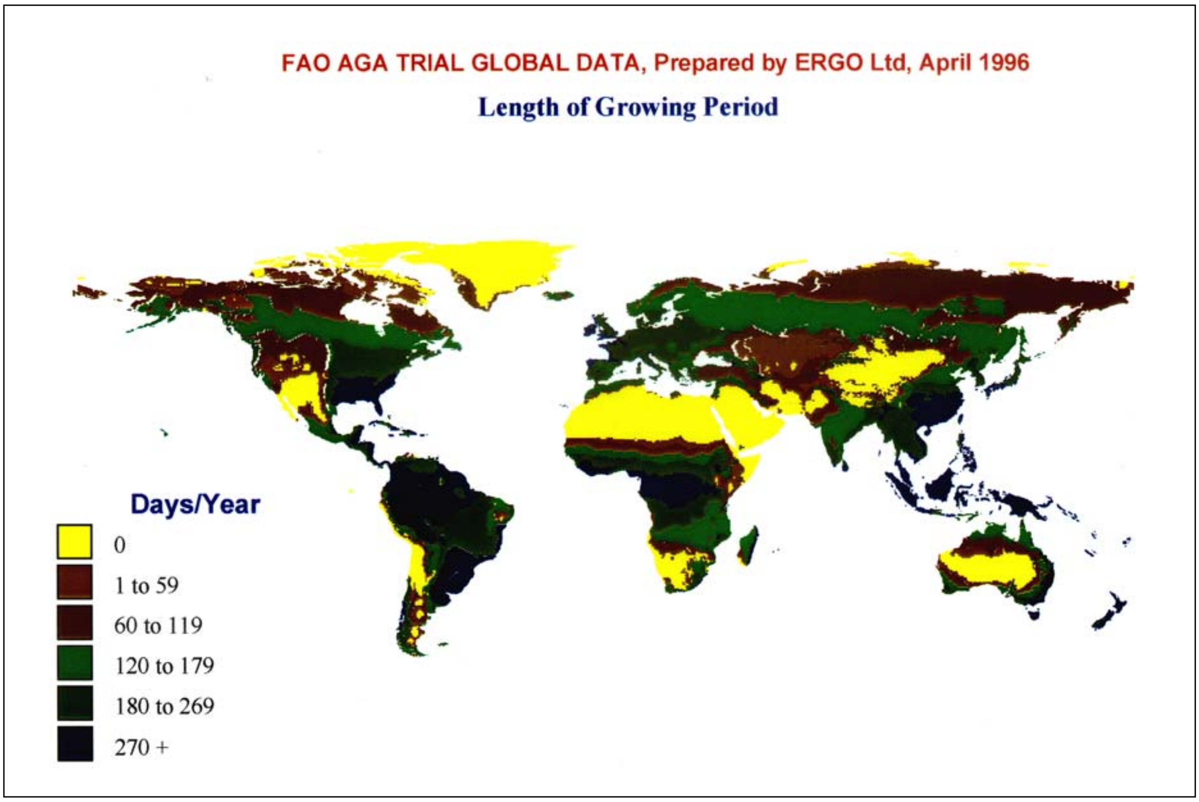

Figure 5. Length of growing period zones; six zones (FAO 1996a)

This study recommends that six zones be discriminated according to length of growing period (LGP), because this is consistent with ongoing work by FAO and others on LGP, complemented by satellite and other data, and estimates of total livestock biomass (Slingenbergh and Wint 1997). There should, nevertheless, be an expectation and provision for these zones to be further subdivided as additional resources and data become available.

These six zones are:

Zone	LGP (days)
Desert	0
Arid	1–59
Semi-arid	60–119
Dry subhumid	120–179
Moist subhumid	180–269
Humid	>270

It is important to appreciate that the choice of agro-climatic zones in this study was strongly influenced by the fact that FAO (1996a,b) studies provided livestock data that could be linked to these zones. The use of human population density data has been a useful step in providing initial estimates of livestock density distribution within countries, and for the most part these estimates appear to be sufficiently accurate to provide information to aid in the targeting and prioritisation of agricultural research. These estimates will be least accurate where the quality of the national data is low, where environmental regulations limit the location of livestock industries (e.g. intensively housed livestock units and feedlots), and where climatic extremes, land degradation or alternative land uses have a greater effect on livestock densities than on those for human populations.

Definition of agro-climatic (and agro-ecological) zones will improve through applying digital elevation models, climate surfaces, plant growth models such as GROWEST (Nix 1981; Zuo 1996), field and remote sensing data, and geographic information systems (e.g. FAO 1997, 1998). The collection of land use and livestock density data in Africa (Corbett et al. 1995; Kruska et al. 1995) and Latin America (G. Hyman, pers. comm.), complemented by local data (e.g. provincial livestock data in the yearbooks of the People's Republic of China), means that before too long it will be useful to revisit the data on livestock density distribution in the light of new and more relevant zonations. International collaboration in assembling and integrating these data sets could be expected to have major benefits in improving the targeting of research and in introducing land management practices that benefit both the environment and resident human and livestock populations.

TASK 2. ESTIMATE THE PROPORTIONS OF OUTPUT OF A COMMODITY PRODUCED IN THE DIFFERENT COUNTRIES IN THE GIVEN AGRO-CLIMATIC ZONES

This task involved estimating, for about 200 countries (the countries that provide data to FAO), the proportions of output of a commodity produced in the adopted agro-climatic zones. As ACIAR pointed out, estimates can be derived using a variety of methods, including (i) knowledge of economic geography; (ii) geographic information systems; and (iii) model-based approaches. Different ways of aggregating, classifying and presenting the FAO data (e.g. within zones across countries) were investigated.

It was anticipated that the methodology for Task 2 would depend significantly on the agro-climatic zones identified within Task 1. The six selected zones to which livestock numbers and commodities would be allocated within countries were desert, arid, semi-arid, dry sub-humid, moist sub-humid and humid. Ideally, biophysical constraints such as soil type and extent of degradation, climate variability, and animal health (e.g. tick and tsetse fly) should also be taken into account in refining this task of determining the number and species of animals that are farmed in different environments (Morley and White 1985). Economic constraints such as high debt or low income levels may also preclude certain options. For example, cattle are more expensive than sheep and goats. There are useful decision trees that may be used to determine which livestock species a farmer (or farming community) might opt for in a given locality. Economic parameters dominate this decision process. There also needs to be an awareness of the proportion of domestic produce that reaches the marketplace and can influence the official statistics.

Table 1 gives the commodities and commodity groups to be covered in the analysis.

Table 1. Commodities and commodity groups to be included in the analysis

	Commodity group to be included	Commodities to be included in the group
1.	Beef and buffalo meat	Beef meat; buffalo meat
2.	Dairy milk	
3.	Other milk	
4.	Sheep and goat meat	Mutton and lamb meat; goat meat
5.	Wool	
6.	Pig meat	
7.	Poultry meat	Chicken meat; duck meat
8.	Eggs	Chicken eggs; duck eggs
9.	Cow hides	
10.	Goat skins	
11.	Sheep skins	
12.	Manure	
13.	Draught power	

Quantitative framework of global livestock production (FAO 1996a,b; Slingenbergh and Wint 1997)

Officers of the FAO Division of Animal Production and Health (AGA) have been engaged in defining a global, quantitative analysis framework for livestock systems and associated livestock mapping software applications. Many of the Division's current activities require at least a continental, but preferably a global, appreciation of livestock distributions in relation to agro-ecological factors and human demographic patterns. A consultancy involving ERGO explored and demonstrated the possibilities of using techniques inherent in geographic information systems (GIS) to produce a database containing information on global livestock distributions, human demographic data, and agro-ecological information. This enables maps to be derived from these data; and possible avenues for future development to be investigated.

National data on domestic livestock numbers for 1996 were obtained by ASIT Consulting from the FAO WAICENT global dataset, along with country agricultural and land-use data for 1994. The data acquired were converted to a spreadsheet format using FAOCONV and EXCEL software. The FAO data may be downloaded from the FAO Internet site (http://www.fao.org/lim500/agri_db.pl)), or from FAO diskettes or CD-ROM.

It needs to be clearly understood that the 1996 FAO data referred to here and elsewhere in this report are the data supplied by member nations for that year. These data should not be confused with the data from FAO (1996a,b) which were based on 1994 FAO data.

Other data sets used by ERGO Consulting (FAO 1996a,b) included raster images of agro-ecological zones (AEZ) and national boundaries, and raster images of global human population numbers at a resolution of 5 × 5 minutes.

Animal population data were available only at national level, and not for within-country agro-ecological zones. In contrast, global human population is available, in image format, at a resolution of approximately 10 × 10 km. By dint of relatively simple, if labour-intensive, image processing and GIS techniques, these can be used to produce human population numbers for each agro-ecological zone within each country.

Methodology for allocating livestock data to agro-climatic zones

In Task 1 it was decided that the agreed agro-climatic zones would be those classified according to the estimated length of the growing period (LGP). These zones are designated desert, arid, semi-arid, dry sub-humid, moist sub-humid and humid (FAO 1996a,b; Slingenbergh and Wint 1997).

FAO and ERGO (Wint, pers. comm.) kindly provided estimates of total livestock biomass for each domesticated livestock species within each agro-ecological zone within each country in an Excel worksheet. Using the mean weights assigned to livestock for each continent (Table 2) (FAO 1996a) it is a relatively simple calculation to estimate the number of 'livestock units' in each agro-ecological zone within each country. These weights reflect both the genotypes and nutritional regimes that dominate each continent.

These estimates were compared with livestock numbers from the FAO Waicent database for 1996. In most cases, particularly those involving developing countries, these estimates corresponded very well with the raw data. In other countries, such as those in the former Soviet Union, there were appreciable differences between the estimates and the raw data. Some differences are to be expected, of course, given the variable quality of the national data, variability about the functions relating 1994 livestock levels to human populations within and between continents (see Table 4 of FAO (1996a)), and other factors discussed by Slingenbergh and Wint (1997). In the case of the former Soviet States, the numbers of sheep and cattle were often significantly less than one would have expected, this not being compensated for by taking goat numbers into account. This may largely reflect deficiencies in the quality of the data, or that ruminant production in these areas is well below that expected. It was decided that the most reliable approach was to use the FAO (1996a,b) analyses to determine for each livestock species the percentage of livestock biomass, livestock units or livestock commodity within each agro-ecological zone within each country. These percentages were then used to reallocate the most recent FAO data (1996) to the different zones. This was aided by the data sort and data filter facilities of Excel, together with some minor programming.

Table 2. Weights (kg) assigned to livestock for each continent (FAO 1996a).

Livestock species	Africa/Oceania	Asia	South America	North America/ Europe/Australia
Equines	125	125	125	125
Cattle	175	325	400	450
Sheep	25	30	50	50
Goats	25	25	40	45
Camels	250	250	250	250
Pigs	30	50	50	50
Buffalo	400	400	400	400
Other camelids	100	100	100	100
Chickens	2	2	2	2

These steps are summarised below:

1. Estimates of total livestock biomass (within species, based on FAO 1994 data) were allocated to agro-climatic zones by FAO (1996b); i.e. by Dr William Wint of ERGO Consulting (Oxford University), in collaboration with Dr Jan Slingenbergh of FAO.
2. Data in Table 2 were used to convert the total livestock biomass to estimates of livestock units within agro-climatic zones within countries.
3. For each livestock species, the proportion of livestock numbers within each agro-climatic zone within each country was then used to allocate the 1996 FAO data for livestock numbers to the different agro-climatic zones. This gave a more up-to-date estimate and, more importantly, ensured that the total of all agro-climatic zones added up to the national total for 1996, according to the FAO database.
4. This process was repeated for the major livestock commodities.

It is of course appreciated that ruminant animals are more strongly influenced by agro-ecological conditions than non-ruminants (e.g. Anon 1992). This report by Winrock International states that the arid and semi-arid zones, which together have 54 per cent of the land area of sub-Saharan Africa, account for 57 per cent of the ruminant livestock measured in tropical livestock units (TLU). The humid zone, making up 19 per cent of the land mass, has 6 per cent of ruminant TLUs. The largest share of goats (38 per cent) and sheep (34 per cent) and nearly all of the camels are found in the arid zone. Most cattle are in the semi-arid zone (31 per cent) and the sub-humid zone (23 per cent). Pigs are mostly found in the humid and sub-humid zones. Poultry are evenly distributed over all zones except the arid zone. Pigs and poultry are also produced in intensive commercial livestock systems that are influenced more by proximity to population centres and ports than by agro-ecological conditions.

The method of allocating livestock numbers to agro-climatic zones on the basis of human density distribution (FAO 1996a) does not directly discriminate between species. However, this is largely compensated for by entering the total number of each livestock species for each country (FAO 1996b). For example, if there are few large ruminants in a country then the area suitable for grazing ruminants will probably be dominated by sheep and goats.

Levels of livestock commodities may be estimated in different ways. For example, FAO provide data on slaughterings and indigenous production. 'Gross indigenous livestock production', defined as 'Meat production from slaughtered animals, plus the meat equivalent of all animals exported live, minus the meat equivalent of all animals imported during the reference period' allows for trade distortions. Emphasis has therefore been on using the indigenous livestock production where these data were available.

A 'livestock commodity production index' is defined as the weight of product per kg of live animal (FAO 1996b). It is therefore an input/output ratio, being 'a very preliminary measure of production efficiency which can be made more complex in due course'. Livestock commodity production indices—representing estimates of the amount of meat or other commodity produced per kg of livestock biomass were estimated for 1994 for each continent by FAO (1996b), as shown in Table 3. Although these estimates were available in spreadsheet form, it was decided to instead use the 1996 data from FAO on the quantities of livestock commodities produced. This was not because the 1996 FAO data were necessarily more accurate, but because they were less likely to be disputed than the derived data produced by FAO (1996b).

Table 3. Calculated livestock commodity production indices for 1994, by continent (FAO 1996b)

Continent	Red meat	Pig meat	Chicken meat	Hen eggs	White meat	All milk
Africa	0.12	1.17	1.05	0.92	1.06	0.44
Asia	0.09	2.12	1.11	1.85	1.66	0.50
Australia	0.36	2.51	3.73	1.37	3.07	1.42
Europe	0.18	2.36	2.44	2.57	2.33	2.27
N. America	0.19	2.22	3.17	1.50	2.67	1.17
Oceania	0.13	2.29	2.52	2.03	2.28	0.02
S. America	0.08	0.91	2.47	1.06	1.65	0.26

Results

The FAO (1996b) approach provides estimates of livestock species biomass within each of the six agro-ecological zones as they occur within each country. These have been based on using a direct ratio between animal numbers and people (animals per person) calculated from the FAO country numbers. It also means that the calculated national total should approximate the FAO national figures.

Figure 6 shows the global distribution of humans, which was used as the major determinant of animal numbers. Figures 7, 8 and 9 from FAO (1996b) show global distributions of cattle, sheep and goats based on FAO 1994 data. Figures 10 and 11 are maps of the livestock production indices for red meat (beef, and sheep and goat meat) and for milk. Global numbers of buffalo are shown in Figure 12, using the FAO map viewer and FAO 1996 data. High densities are found in China, correlated with the high human population (Slingenbergh and Wint 1997). Cattle concentrations are most pronounced in India, Europe, North America and Argentina. Small ruminants, especially sheep, are shown to be most abundant in Australia, New Zealand, southeastern Europe and the United Kingdom. Other ruminants monitored by

FAO include buffalo, camels and other camelids (alpaca, llamas, vicuna), and equines. Care needs to be taken in interpreting Figure 10, in particular, in that cattle, sheep and goats are capable of producing milk, skins, fibre, draught power and manure in addition to meat.

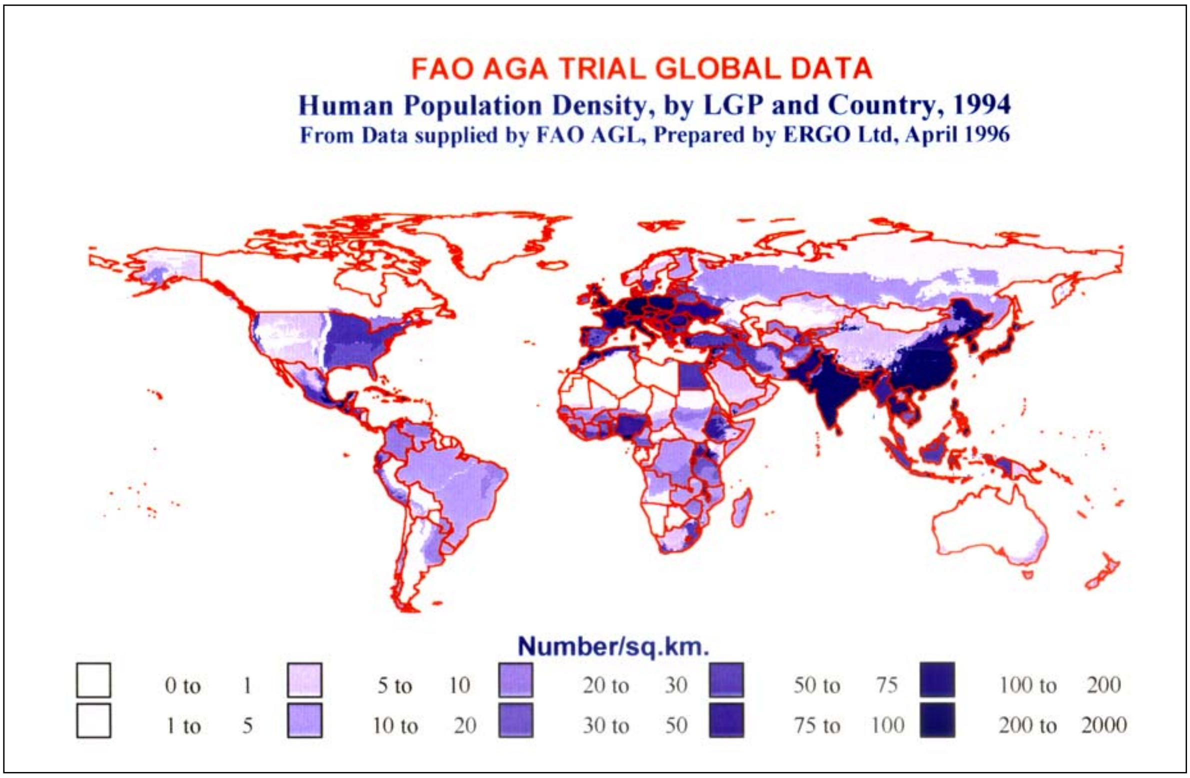

Figure 6. Human population density, by LPG and country (FAO 1996a)

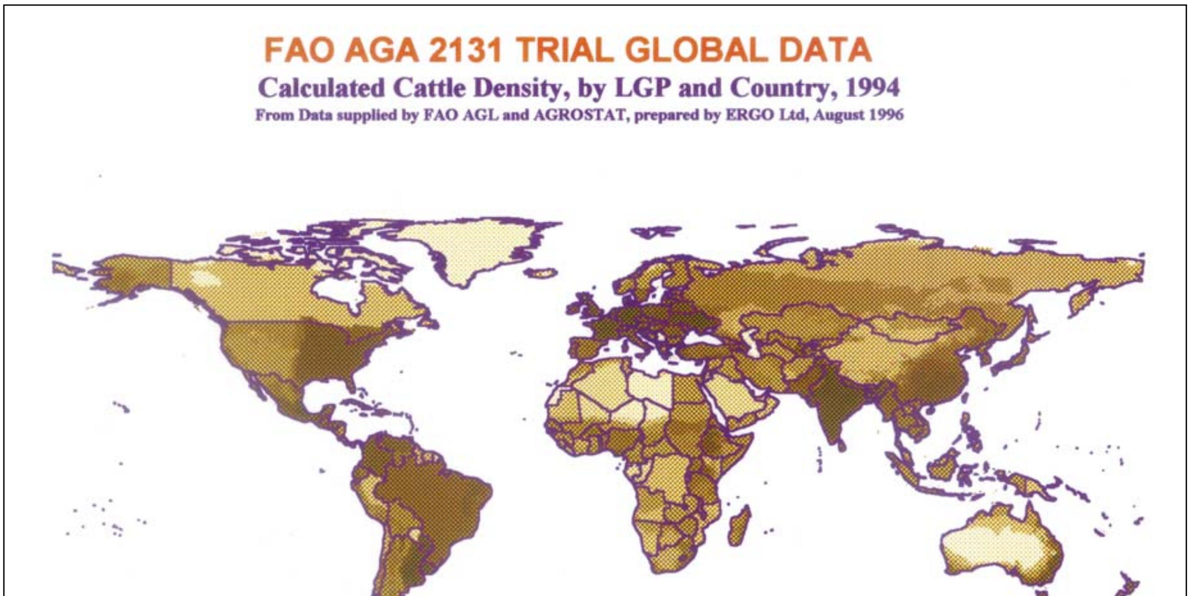

Figure 7. Calculated cattle density, by LGP and country (FAO 1996b)

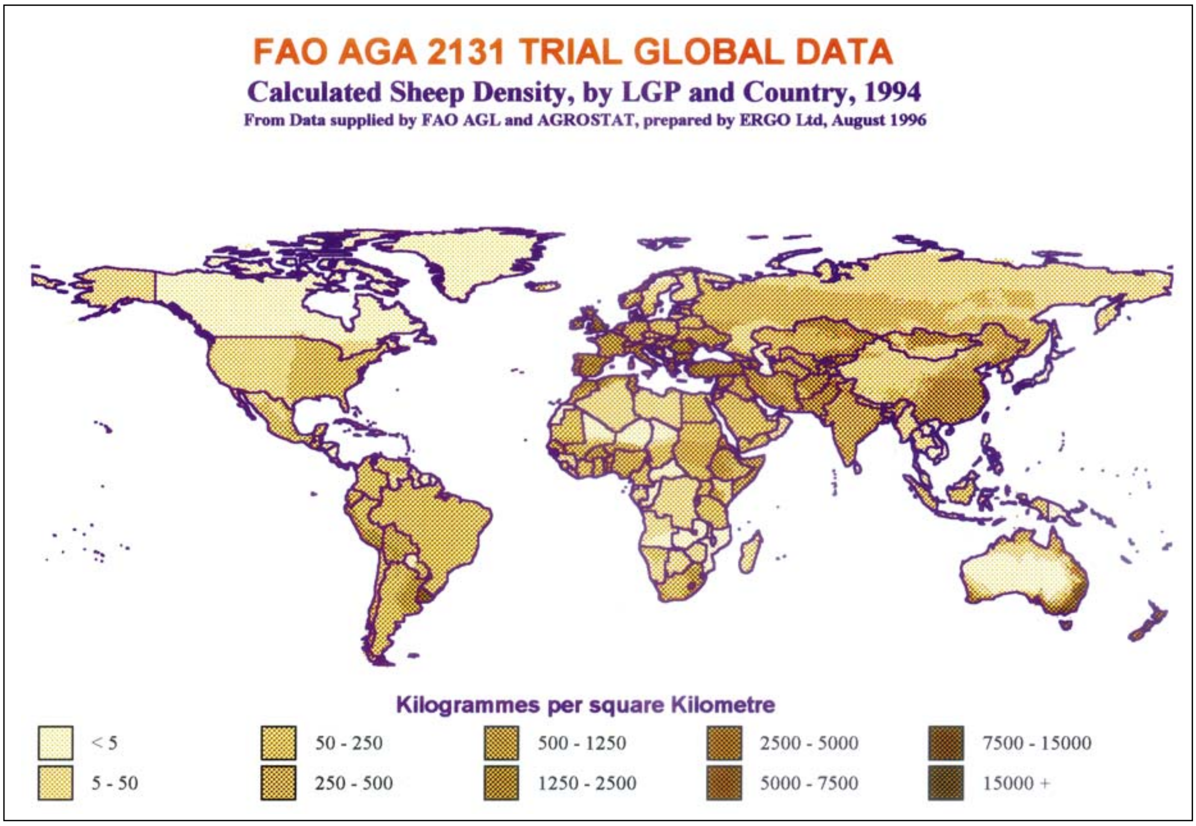

Figure 8. **Calculated sheep density, by LGP and country (FAO 1996b**

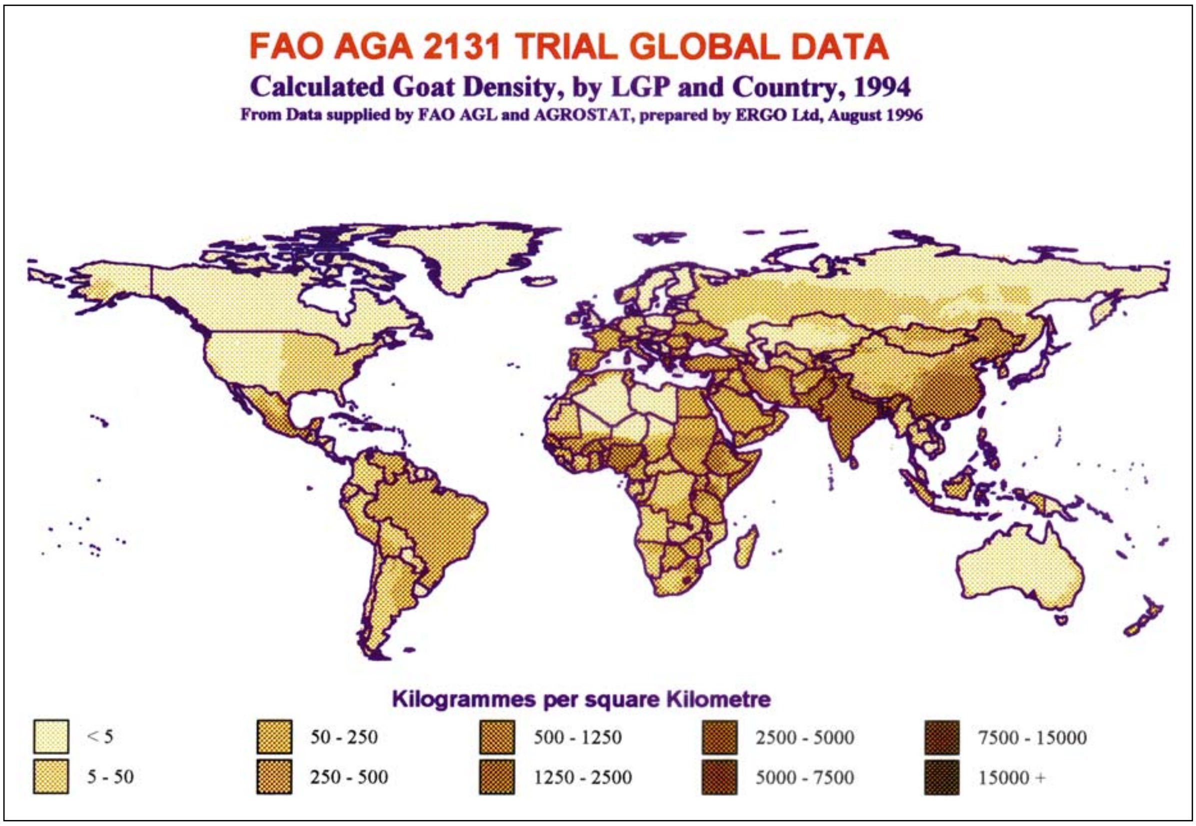

Figure 9. **Calculated goat density, by LGP and country (FAO 1996b**

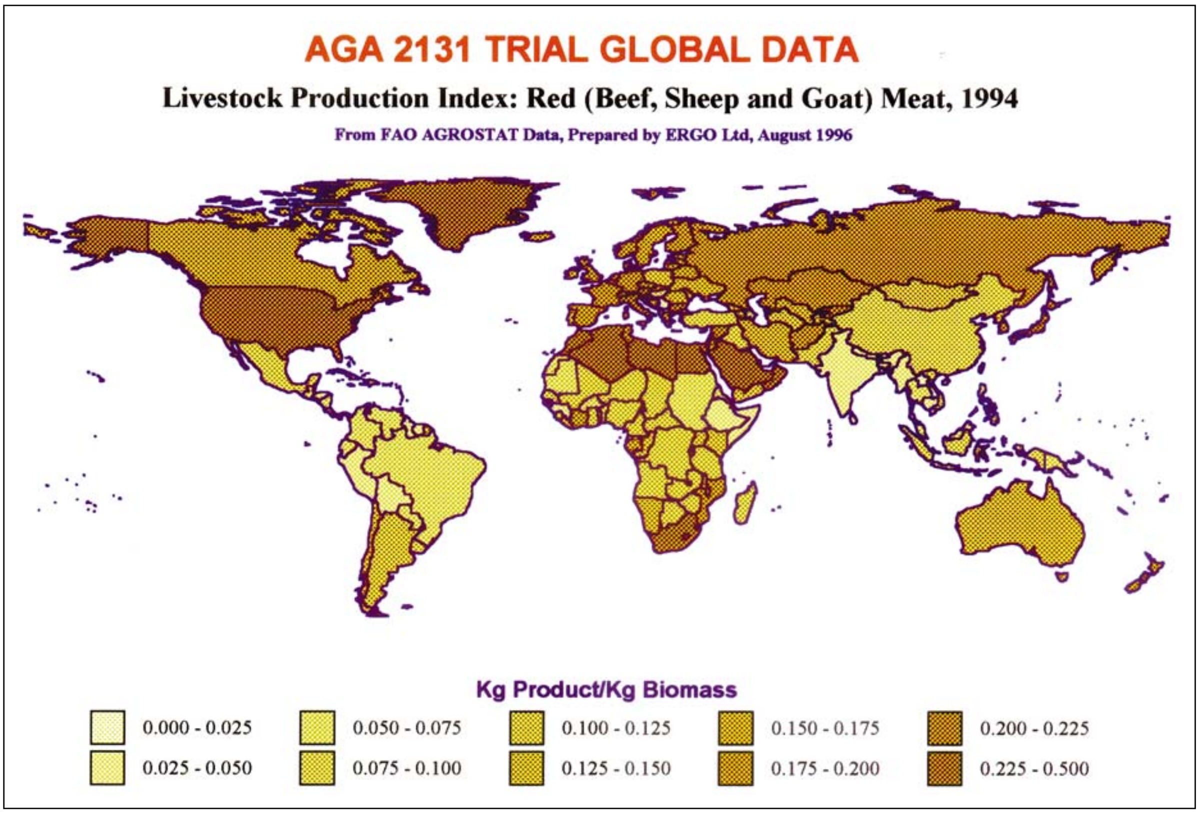

Figure 10. Calculated red meat (beef, and sheep and goat meat) production index (FAO 1996b)

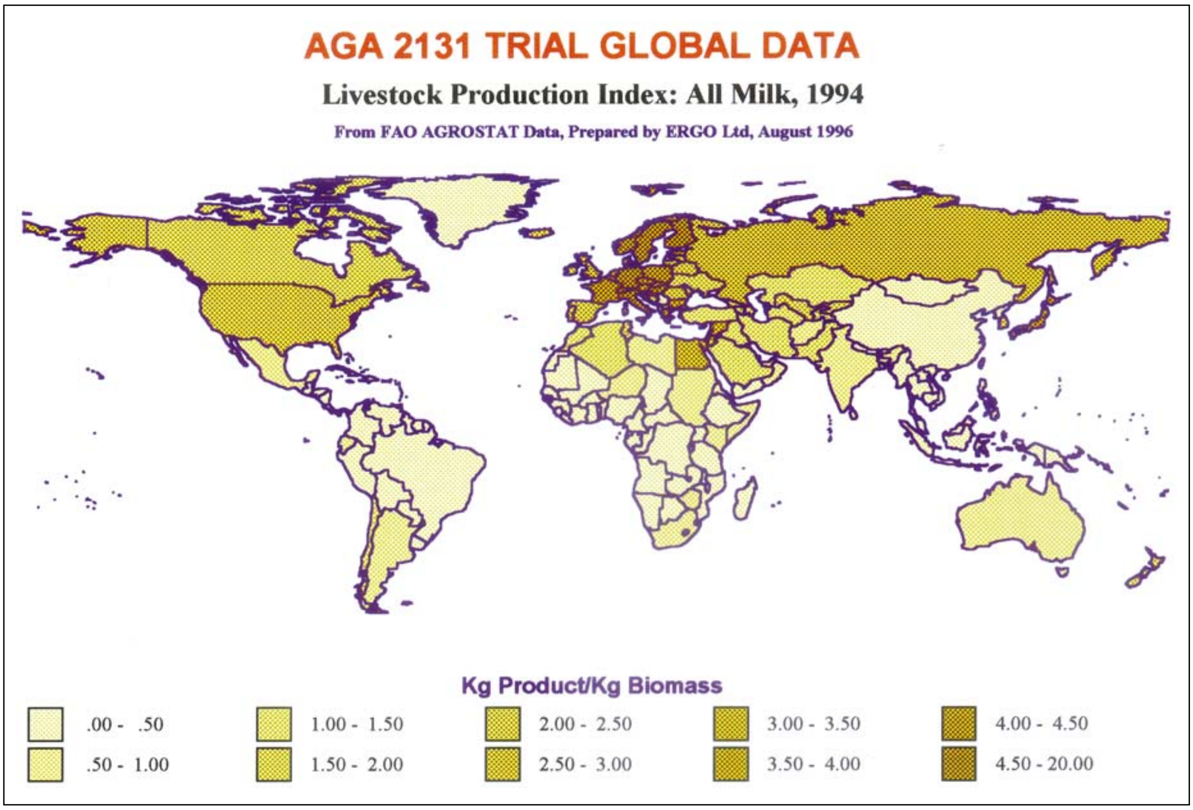

Figure 11. Calculated all milk production index, by country (FAO 1996b)

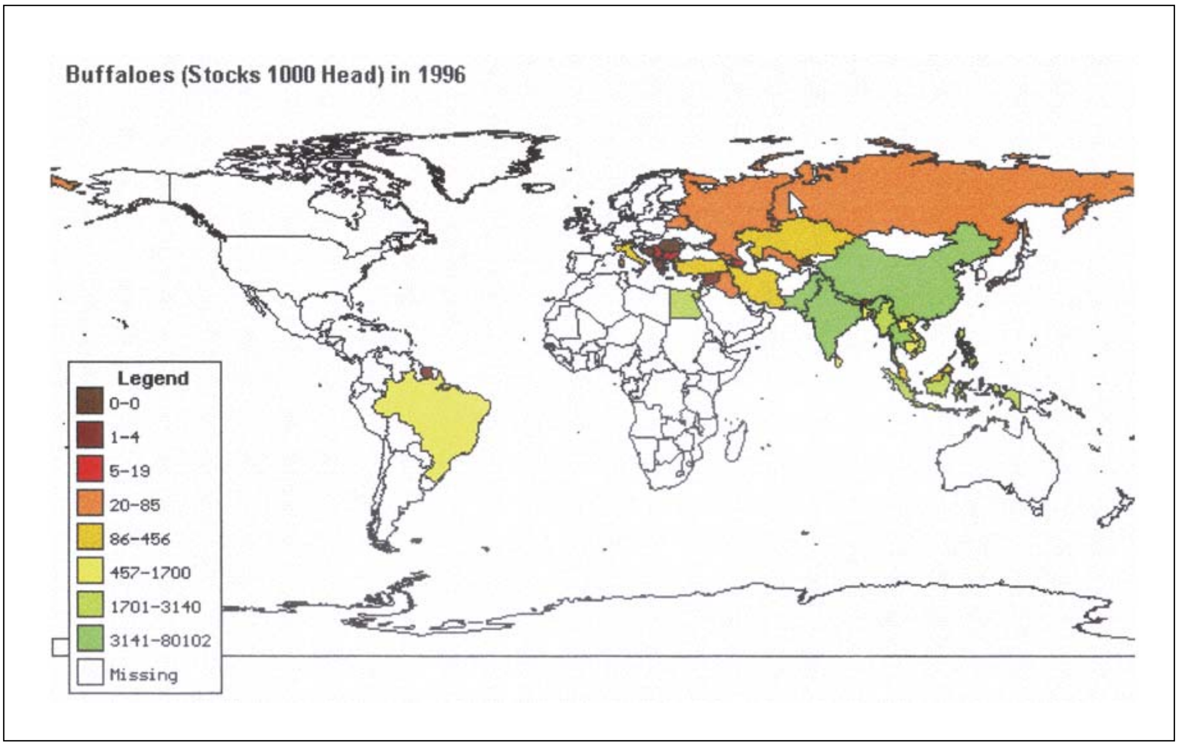

Figure 12. Global distribution of buffalo numbers by country in 1996, FAO

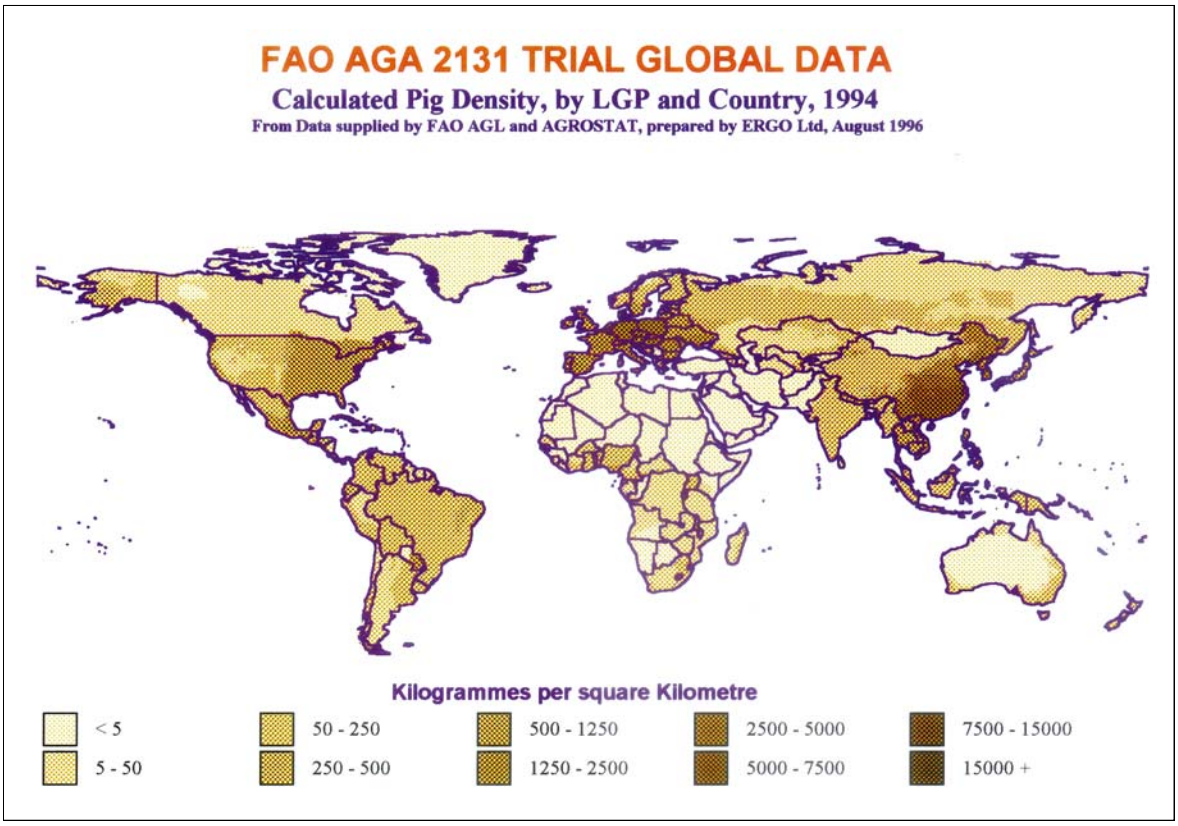

Figure 13. Calculated pig density, by LGP and country (FAO 1996b)

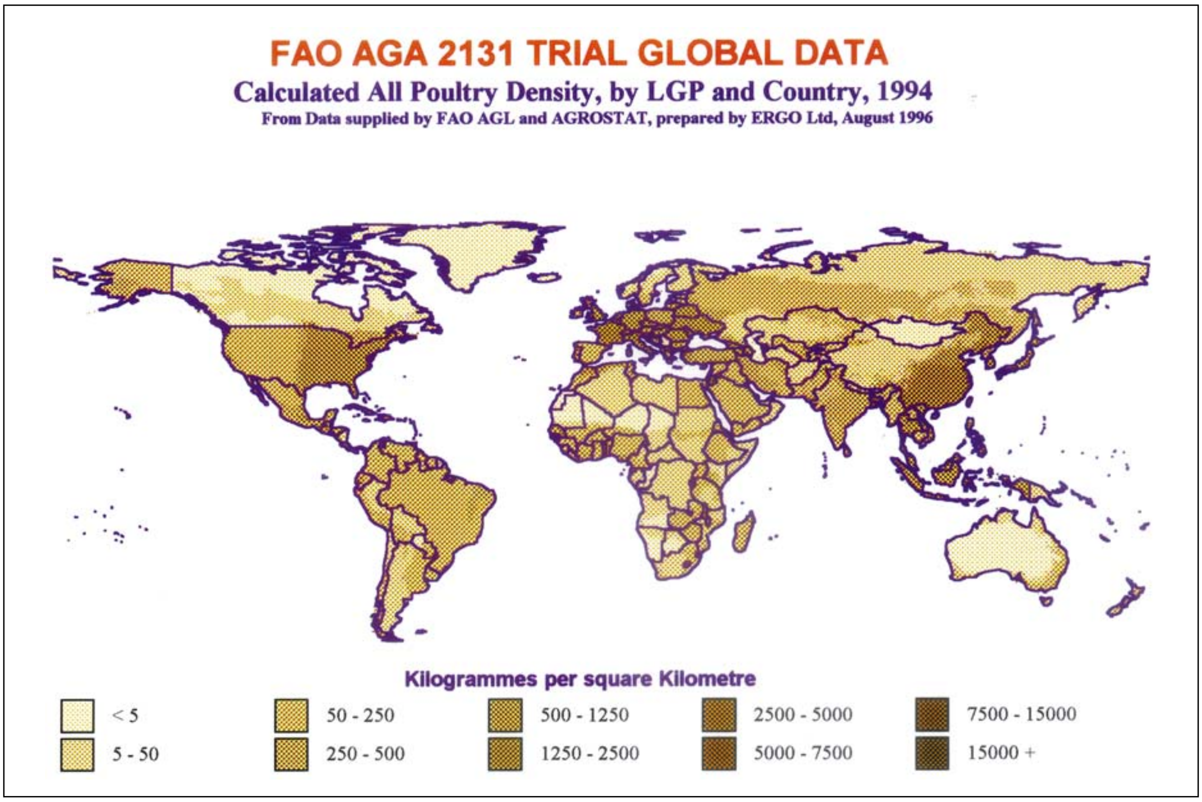

Figure 14. Calculated poultry density, by LGP and country (FAO 1996b)

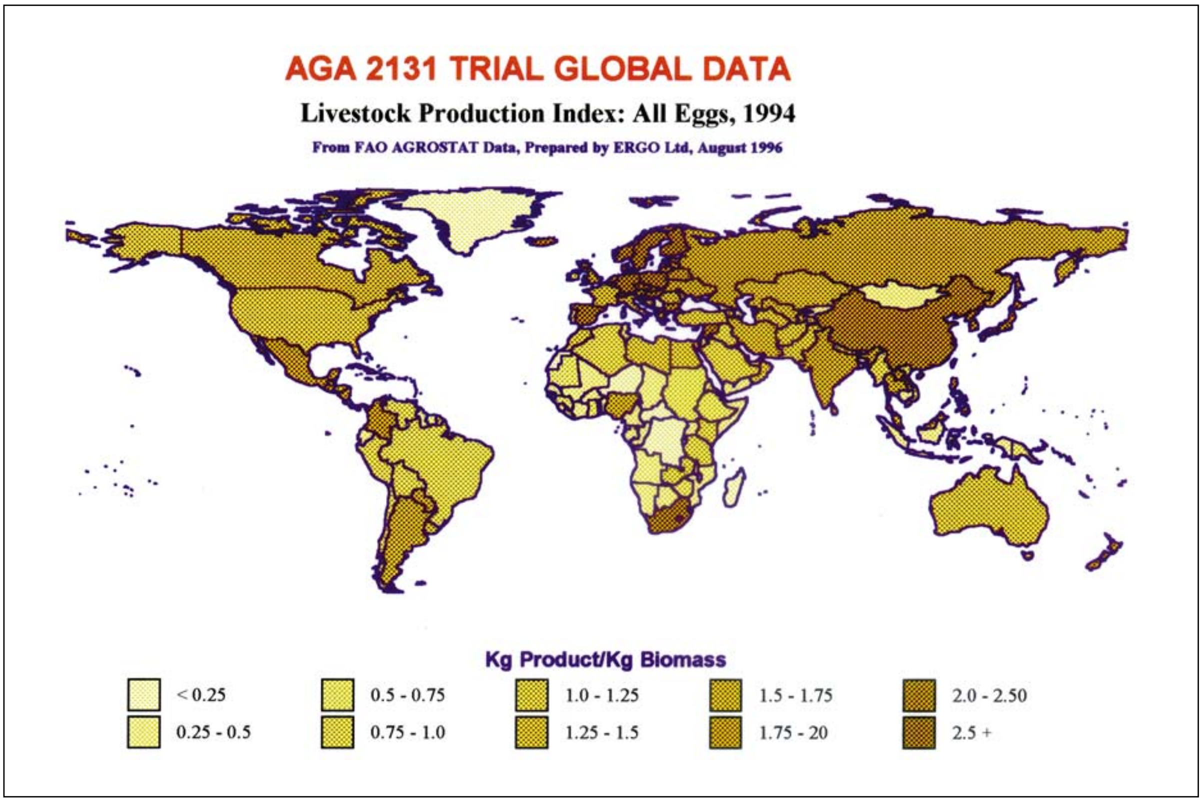

Figure 15. Calculated pig meat production index, by country (FAO 1996b)

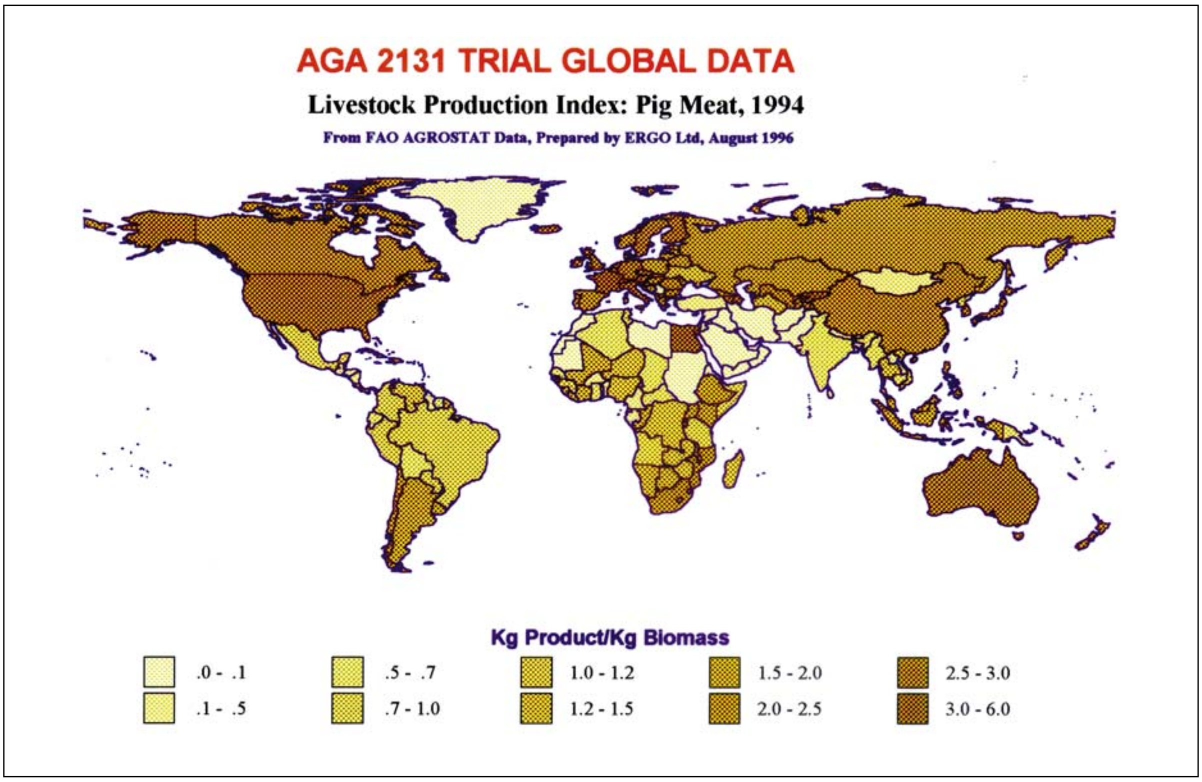

Figure 16. Calculated production index for all poultry eggs (FAO 1996b)

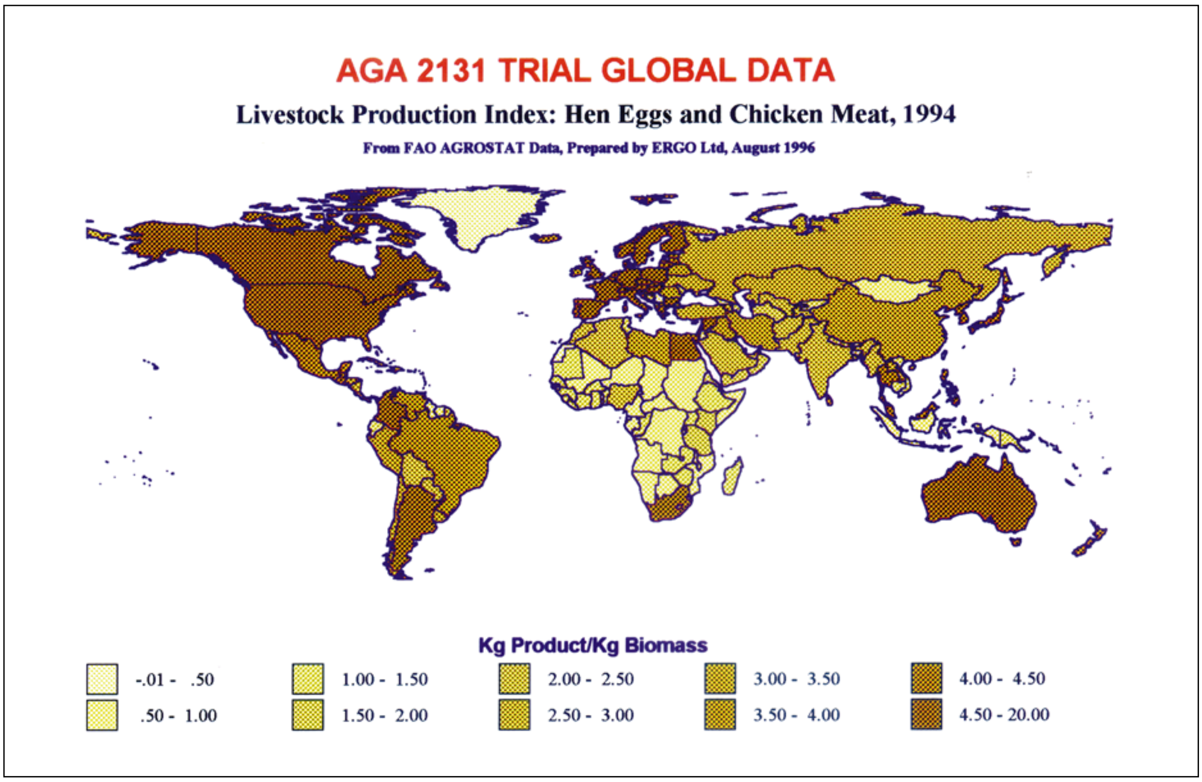

Figure 17. Calculated production index for hen eggs and chicken meat (FAO 1996b)

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.

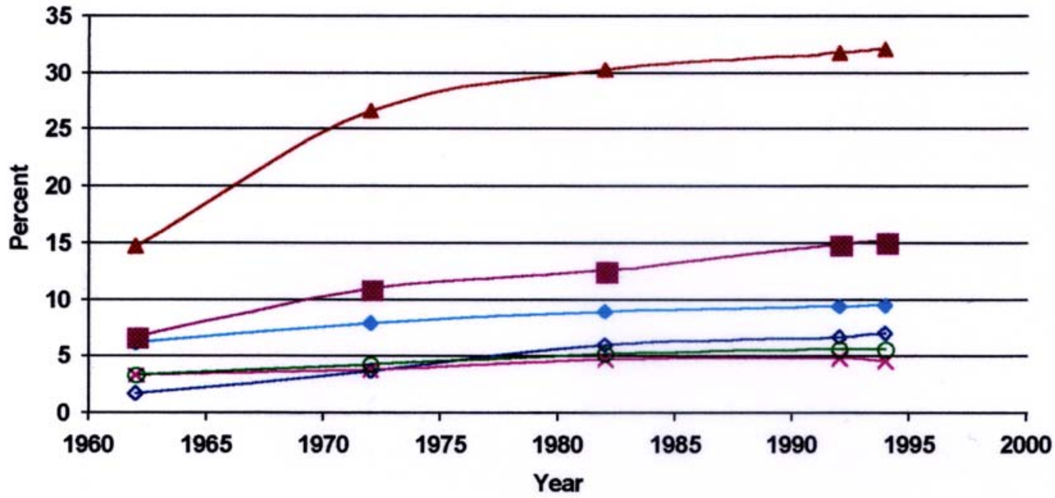

Figure 18. Non-ruminants as a percentage of total biomass by agro-ecological zone (after Slingenbergh and Wint 1997)

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 (km^2 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 15–20ºC. 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 25–30ºC.

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 are 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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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 Expats	
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 Expats	
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 Technología 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:	4.5%
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 Voltaique de Recherches Agronomiques et Zootechniques (IVRAZ)

Laboratoire de Diagnostic et des Recherches Vétérinaries (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 Vétérinair (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 National de Investigação Agraría Amilcar Cabral (INIAAC)

ISNAR 1991 (Beintema et al. 1994a): Instituto National de Investigação Agraría (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 Rercherches 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 Agropecuaries (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 Columbiano 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'Elevage 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'Elevage 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 Insstitute.

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 Sciece 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 Tecnoligía 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 $s as % of GNP	4.1
Education $s 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 $s as % of GNP	–
Education $s 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 $s as % of GNP	–
Education $s 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 $s as % of GNP	4.0
Education $s 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 $s as % of GNP	–
Education $s 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 $s as % of GNP	–
Education $s 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'Elevage 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 Institute 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 Agricolas (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'Elevage 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'Elevage—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 Maiduiguri 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 Expats = 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%
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 Expats. 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 Investigacion Agraria y Agroindustrial (INIA), under Ministry of Agriculture and Food. Also National Agicultural 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 Supériere 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 Institue. 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 Makarere 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 Medecina 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	–