SECTION II

Methodologies and guidelines

4. A synthesis of methodologies available for national feed assessments

4.1 CALCULATING GROWTH IN LIVESTOCK FEED REQUIREMENTS

Although the primary focus of this document is assessment systems for national feed supplies, the need for such feed assessment systems is fundamentally driven by the question of whether feed supplies can meet future feed demands. The implications of feed availability for food security depend upon a corresponding assessment of feed demands.

An approach for calculating present and future demands for human food consumption is described in Chapter 7. Total projected food demand is calculated by multiplying projected per capita consumption rates by projected human population growth. Demands for animal source foods are included in this projection, based on current and predicted future dietary composition patterns. Using projected demands for animal source foods, the demands for animal feeds are calculated by employing feed conversion ratios.

The demands for livestock products are spatially distributed and mapped using maps of human population distributions. Consumption is mapped using the spatial distributions of rural and urban populations from the Global Rural Urban Mapping Project (GRUMP) and total human population numbers from projections made by FAO and other international organizations.

The diversion of crop production to livestock feeds is also a component of the human food requirement. Projected crop production requirements can be calculated by projecting future demands for livestock feeds. Crop products available to humans are calculated by subtracting crops used for feed, seed, waste and industrial production.

4.2 FEED SUPPLIES FROM CROP-BASED SYSTEMS

The approaches that have been developed to assess livestock feeds in crop-based or mixed crop-livestock systems are heavily reliant on crop production statistics that are developed by national government agencies. This is true in the highly developed system in Switzerland as well as the more recently developed system in India. Crop productivity data may take the form of biomass of crop and associated crop residues per unit land area. These data are then combined with land use data that characterize the amounts of land cover with different crop types.

A key aspect of this approach is the system that is utilized for categorizing land use/land cover and crop types. At some point, land cover mapping is required, in which land use/cover types are delineated spatially. The classes may be by crop species and/or cropping systems or more aggregated classes may be utilized. For improved accuracy, cover types would recognize variations in soils and climate that affect productivity. Alternatively, cover types could be overlaid with soil fertility and climate maps, such as precipitation and length of growing season, to develop a classification that accurately distinguishes crop types and differences in potential productivity due to environmental limitations.

The second primary data input is crop productivity. It is beyond the scope of this Manual to describe the various methods that are employed to estimate crop production. As noted, the feed inventories most often obtain crop production data from government agencies, so that aspect lies outside the feed assessment system. Undoubtedly, the data are ultimately based on an abundance of agricultural research and data obtained from commodity markets within the country. An important consideration, however, is the matching of crop production data to crop/land use/land cover data. A common classification system must be developed, or a system for converting between the classification system used for crop production data and the system used for crop/land use/cover data, in order to perform the calculations of total production for each of the crop/land-use/land-cover types.

Although a case study that employs remote sensing to estimate crop productivity is not presented here, there is a potential for doing so. Remote-sensing data are used as inputs to models of global primary production, as described above in the "Global-scale modelling" section. Remotely-sensed greenness or green biomass indices, integrated over time, can be used as a correlate of primary production along with the use of ancillary data such as crop-specific light use efficiencies, solar radiation and soil water availability.

Calculation of livestock feed availability from crop production data inevitably entails the use of factors which convert between total biomass production and actual feed biomass. In India, for example, an extraction ratio is used: the ratio of feed to total crop harvested (Chapter 9). In an assessment for China, extraction rates such as the proportions of crop comprised of grain, straw, etc. were used (Simpson *et al.,* 1994). The amount actually utilizable by animals must also consider wastage, losses in transport and storage, and fertilizer use. The basis for estimating these conversion factors is somewhat of a concern, because little documentation is provided for their sources. It is apparent that in many cases estimates are based upon little data and are rough approximations. Further research could be targeted to improving the data upon which such extraction ratios are based.

Conversion factors are also employed in calculating crop residues and by-products that are increasingly utilized for feed. In India, a conversion factor is used: the ratio of tonnes of utilizable by-product to tonnes of crop harvested (Chapter 9). The assessment for China (Simpson, 2006) included a partitioning of total crop production into the primary product as well as any by-products that could be utilized as feed. The section above on "Crop residues in mixed crop-livestock systems in Africa" employs factors that have been developed through more detailed studies (Kosilla, 1998). As with the extraction ratios, the sources of these conversion factors are not very apparent, and there is considerable room for the development of sound data sources. Considering the increased reliance on crop residues and by-products particularly in the developing world and in heavily populated regions, and the projected increased use of these sources, these data will become increasingly important.

Although few details have been provided here on the flows of feeds into and out of countries through imports and exports, these must be taken into account in national level feed balances. The Swiss system explicitly considers trade flows in its annual national feed balance assessment. It also considers changes in standing stocks, or reserves, all of which are necessary for predicting future capacity to cope with feed deficits, as necessary. Presumably, import and export data are the purview of entities concerned with commodity trading and market activities.

Another source of livestock feeds is by-products from food processing industries. In the Swiss example (Chapter 8), industrial food processing by-products that can be utilized for feed are estimated from industrial sources or agricultural offices. It is likely that this approach would be useful in many, if not most, countries where this is an important feed source.

The usability of crop-based and industrially produced feedstuffs by livestock is additionally affected by economics, which is in turn affected by the use of these feedstuffs for alternative, competing uses. For example, the use of molasses by livestock may be prohibitively expensive due to the high prices that humans are willing to pay to utilize molasses for food. Biofuels could become another significant competing demand for feedstuffs, which would also drive prices higher. Thus, merely accounting for "available" feeds will not work; their actual and potential uses will have to be considered. Price data will be key to availability for livestock. Assessments should relate feed prices and their nutritive values to the expected livestock products and their market prices (e.g. rice bran and pig live weight; sorghum and wheat straws; and rural and peri-urban milk prices).

4.3 FEED SUPPLIES IN SPATIALLY EXTENSIVE SYSTEMS

For spatially extensive livestock systems, remote-sensing data are indispensable. However, key ground data on forage biomass are also necessary for converting remote-sensing data to forage biomass amounts. The extensive nature of these systems also requires the use of a variety of spatially explicit data, GIS processing and modelling capabilities, as outlined in Chapter 16 on "Technologies, Tools and Methodologies for Forage Evaluation in Rangelands". In this chapter, four examples are given of systems that have been developed in which remote-sensing data, along with ground-based forage sampling data, are used to assess forage situations in pastoral regions. Two of these were developed as early warning systems to alert governments, aid agencies and pastoralists to developing situations of food shortages caused by drought or severe winter weather. A system was developed for the Sahel that ingests remote-sensing data on green biomass and water, along with additional GIS data (Chapter 10). A livestock early warning system (LEWS) was developed and has been employed in Africa as well as Asia (Chapter 12). A powerful feature of the LEWS is that it employs vegetation simulation modelling, driven by statistically projected precipitation data to estimate future risks of feed shortages. Remote-sensing data can also be used as inputs to relatively simple models of primary production, in combination with data on light use efficiency, solar radiation and temperature (Chapter 13). Yet another system employs locally installed receiving stations for downloading remote-sensing data (Chapter 11). The data are then processed, in combination with ground data on forage biomass, to develop forage biomass maps.

When extensive ground-based survey data are available, it is possible to carry out national level forage assessments without the aid of remote-sensing data. An approach for assessing forage resources at the national level in the United States relied on course estimates made by the U.S. Soil Conservation Service (SCS) of typical forage production values for range site classes contained in soil surveys (Joyce, 1989). These surveys were carried out over many years through the federally-funded activities of the SCS.

4.4 TECHNOLOGIES, TOOLS AND METHODOLOGIES FOR FORAGE EVALUATION IN GRASSLANDS AND RANGELANDS

Rangelands consist of grasslands, shrublands, savannahs and woodlands, and provide a significant fraction of the world's livestock feed resources (75 percent), particularly in regions with arid or semi-arid climates, and in developing countries. However, rangelands are often spatially expansive, heterogeneous, undeveloped in terms of accessibility, and low in human population presence. Unlike crops which are harvested and sold in markets in measured quantities, rangeland production is often imprecisely estimated, if at all. Production varies temporally with climatic conditions so mean values, if they are available, are often imprecise. Fundamentally, it is economically infeasible to invest sufficient resources in ground-based monitoring to provide the necessary data for national rangeland feed assessments. It has therefore proved especially difficult to develop national level feed inventories for rangelands.

Over the last three decades, there have been a host of technological developments in GIS, remote sensing and computer modelling of rangeland productivity that could be systematically applied to assessments of rangeland livestock feed situations over broad spatial scales. These technologies can be closely coupled with field-based sampling approaches that also have benefitted from recent technological advances such as GIS-based sampling protocols and near-infrared reflectance spectroscopy (NIRS) analysis of forage quality. An overview of these technologies is provided in Chapter 16.

Two suggestions are given for increasing the capacity to scale up a limited number of field-based forage biomass estimates to large areas. One is the use of field estimation techniques such as double sampling, which considerably reduces sampling effort and time. If done properly, aided by statistics, accuracy is little compromised. The second suggestion is to employ GIS and remote sensing-based spatial data to more effectively stratify sampling. Adequate sampling of each stratum permits the accurate scaling up for each stratum, and in aggregate, to a landscape or region.

Forage quality is as important as forage quantity in rangelands, because it is very often limiting and temporally variable. Without an estimate of forage quality, it is impossible to know what fraction of total plant biomass actually constitutes "feed". Indeed, while there may appear to be an excess of plant biomass, it may not all be consumable and, in the case of ruminants, material of low quality can reduce passage and forage intake rates. Direct estimation of forage quality over large areas and sufficient frequencies is prohibitive. However, NIRS has been shown capable of processing a large number of samples in a cost effective manner. For a national feed inventory, NIRS may be the most practical approach for assessing forage quality.

As shown in case studies for the Sahel, Tibet, Mongolia and southern Africa, remote sensing has proved to be indispensable for monitoring and assessment of the livestock forage situation over large areas. Chapter 16 provides an overview of the use of remote-sensing data for this purpose. In particular, remotely-sensed vegetation indices such as the NDVI have now been highly developed and widely applied. The data are commonly used as a direct correlate of green biomass and productivity or as an input to models which calculate productivity from the amount of radiation intercepted by green leaf biomass.

Though more demanding in terms of technological sophistication and expertise, dynamic simulation modelling of rangeland vegetation productivities, animals and ecosystem dynamics has advanced considerably over the last three decades. The models generally require a considerable amount of data but, once parameterized and tested, their capabilities extend well beyond purely empirical approaches. One unique feature is the capability to represent seasonal and inter-annual temporal dynamics in forage quality and quantity, and the potential effects of these variations on energy and nutrient consumption by livestock. Temporal variations can be more significant than mean or total annual quantities of forage production because periods of scarcity may ultimately prove to be what determines numbers of livestock that can be sustained.

Secondly, models can be implemented spatially, based upon GIS and remote-sensing data inputs, to consider the consequences of heterogeneity in topography, soils, vegetation and water availability. Such heterogeneity is extremely significant to mobile large herbivores (Coughenour, 2008). Often, resources are concentrated in key areas of the landscape, particularly during periods of scarcity. Third, the models are usually based on a mechanistic understanding of the processes involved in plant growth and animal production, as well as the ways that these processes respond to environmental variables. Fourth, the models are integrative, linking together climate, soils, vegetation and animals. They not only consider linear causes and effects, they also often consider feedbacks, for example of animals on plants and soils. Fifth, since they are driven by climate data, they have prognostic capability, that is, they can be used to make projections based on the current status of soil moisture, green biomass and likely scenarios of upcoming climatic conditions. Such models can also be used to examine outcomes of "what if" scenarios of climate, policy, livestock and human population increases, land use changes, and so on.

The effects of spatial distributions of topography, water and vegetation cover on livestock forage availability can be considered using GIS-based approaches. Although remote-sensing data can appraise vegetation biomass over large areas, not all of this biomass may be available due to unsuitable topography or long distances to water. Feed assessments must consider these limitations. Chapter 16 suggests possible approaches to this problem. Similar approaches were taken in the case study for the Sahel (Chapter 10). It is also possible to consider effects of topography and water on livestock spatial distributions in an ecosystem modelling approach (e.g. the SAVANNA model) (Chapter 15).

Potential stocking rates can be calculated by combining estimates of available forage with forage requirements per animal, the fraction of forage that can be consumed without causing degradation, and amounts required by wildlife and lost to fire. Actual stocking rates may be higher as a result of feed importation. Animal requirements can be calculated in considerable detail using nutritional balancing tools or models such as NUTBAL[4], which determine energy and protein requirements for maintenance and production. This is essen-

[4] NUTBAL is a software application whose primary purpose is to provide the livestock industry with the means to monitor the nutrient concentration in an animal's diet and determine if the current diet is sufficient to meet performance goals set by the producer.

tially the same approach as is utilized in calculating feed balances. The fraction of forage that can be sustainably consumed, also known as an allowable, or proper use factor, is highly significant, yet given little attention. It may vary widely, depending on plant species, soil fertility and the mode of grazing. The amounts that should be allocated to wildlife utilization, biodiversity or sustainable ecosystem service provision must also be carefully determined and factored into the feed availability assessment.

A computerized data management and quality control system will be necessary for a successful national feed assessment programme. Field data from across the country would have to be fed in, organized and made readily retrievable. Considerable amounts of data are involved in GIS, remote sensing and modelling technologies needed to cover large, diverse regions. While these technologies will be invaluable for rangeland feed assessments as described above, they would also be invaluable for crop-based feed and mixed crop-livestock systems, inasmuch as the productivities of these vary spatially and are intrinsically linked to land use and land cover. Feed assessment models, whether they simply consist of a series of calculations or are more elaborate dynamic simulations, involve organized data inputs and outputs, as well as pre- and post-processing.

4.5 FEED BALANCES FROM NATIONAL FEED ASSESSMENTS

While assessments of feed inventories and feed productive capacities provide critical information, the sufficiency of the feed supply can only be gauged relative to the demands for feeds. Essentially, this comparison between livestock requirements and feed supplies constitutes the feed balance. The feed balance can be calculated in terms of energy or specific nutrients or the amount of feed that would need to be imported to meet a country's feed requirements. Chapter 14 examines the basic methodologies involved in determining a feed balance. The steps taken in calculating a feed balance are: 1) estimation of feed supply, accounting for seasonality of supply, and feed losses due to inefficiencies, wastage, pests and disease; 2) quantification of animal numbers and production traits, in terms of live weight gains, milk production, egg production, and so on; 3) estimation of animal feed requirements, in terms of energy and nutrients, based upon animal species, age class, reproductive status and body mass; and 4) estimation of energy supplied from available feeds, accounting for factors affecting feed intake such as breed, age and feed accessibility.

In Switzerland, livestock census data obtained from government census units are combined with animal energy and protein requirements, which are based on research. In India, a similar approach is utilized, and it is recognized that livestock populations must be broken down by age, sex and functional classes as well as species, because requirements vary accordingly. Nutritional requirements may be quite simply expressed, for example, in terms of kg of feed per kg of body weight per day, or they may be more detailed, based on accurate estimates of energy and protein requirements for different breeds, body weights and animal functional types (Chapter 14).

Methods for assessing feed demands on a large scale are derived by scaling from data collected at local level. The multi-scale sampling approach described by Dikshit and Birthal (2010) is an example of a systematically designed sampling scheme that enables scaling up from households to villages, to districts and ultimately to the nation. Another approach is a stratified cluster design for village level surveys (Erenstein and Thorpe, 2010). These approaches highlight the importance of obtaining detailed data on the ground in order to characterize the wide range of variability and complexity across livestock production systems.

In spatially extensive systems, it is useful to develop feed balance maps, as was done in the Sahel (Chapter 10). Such maps identify locations where feed is in short supply or in excess, which can be responded to with livestock movements. Livestock distribution maps are developed based on information on the locations of pastoralists and their livestock. These are used to compute and map forage requirements. The requirements map is then compared with a map of feed availability to derive a map of feed surplus or deficits, which is useful knowledge for development planning and food relief efforts.

On larger scales (regional through global), maps of livestock distributions can be similarly used to assess the spatial distribution of livestock feed requirements in relationship to demands. Essentially, this would be equivalent to calculating and mapping the feed balance. The section below on databases provides examples of recent global livestock mapping efforts, although the uses of such maps to assess feed balances have been limited.

At a higher level, there is also concern for the human food balance, particularly the degree to which animal-source foods are able to meet human demands. The methodology employed in such assessments invariably involves the use of human population mapping, combined with per capita animal source food requirements (Chapter 7).

4.6 DATABASE SYSTEMS AND NATIONAL FEED ASSESSMENTS

National feed assessments will inevitably involve the collection and management of large amounts of data. Database systems are therefore an important component of the methodologies. The details of such systems cannot be provided here. However the reviews of existing feed assessment systems all point to database implementations of some sort. In highly developed systems, there is a centralized government database managed by a government agricultural statistics unit, as in Switzerland. Statistics are made available via reports and the internet. Accessible, user-friendly livestock feed data systems can also be developed, as has occurred in India. Clearly, the advents of spatial databases and GIS have made livestock feed assessments easier to carry out, and it has made the assessments more accurate. In crop-based systems, assessments are built on spatial data pertaining to crop/land use/land cover. In spatially extensive systems, the assessments almost entirely depend upon capabilities to process remote-sensing and GIS data, and in some cases, the capability to feed these data into forage production models, which are also spatially explicit. Examples of integrated data flow systems are provided in the descriptions of systems developed for the Sahel (Chapter 10) and Mongolia (Chapter 12). Further discussions of data processing capabilities are provided in Chapter 16.

While the aim here is to develop guidelines for national level feed assessments, awareness of FAO databases is potentially useful, in that there is a connection between FAO and country level databases. Given that FAO obtains its data from individual countries, it is true that the countries and not FAO are the ultimate data sources. However, FAO organizes the data in a particular way and makes it readily available. Increasing the accuracy of country level data on livestock feed availability and demands would consequently improve FAO's databases. As seen above, global scale estimates of human appropriation of NPP, as well as impacts of livestock on carbon balances, are ultimately tied back to FAO and thus country level assessments.

Since 1950, FAO has been preparing a World Census of Agriculture (WCA) (FAO, 2010 - http://www.fao.org/economic/ess/ess-wca/en/). The 2000 Programme was the sixth in the series. Since 1950, the WCA has been helping countries to carry out their national agricultural census at least once every decade using standard international concepts, definitions and methodology. WCA 2010 provides countries with a flexible approach to the collection of agricultural data on a variety of subjects in an integrated manner. FAO encourages countries to develop their programme of census and surveys, keeping in view their priorities, practices and resource availability. The following websites describe relevant methodologies.

www.fao.org/economic/ess/ess-wca/wca-guidelines/en/

www.fao.org/docrep/009/a0135e/A0135E04.htm

www.fao.org/docrep/009/a0135e/A0135E05.htm#ch8.3

Member countries provide the reports of their agriculture censuses to the FAO Statistics Division, which then disseminates the data through its website. FAOSTAT (http://faostat.fao.org) provides time-series and cross sectional data related to food and agriculture for some 200 countries.

The national version of FAOSTAT, CountrySTAT (http://www.fao.org/economic/ess/ess-capacity/countrystathome/en/), is being developed and implemented in a number of target countries, primarily in sub-Saharan Africa. It will offer a two-way data exchange facility between countries and FAO, as well as a facility to store data at the national and sub-national levels. CountrySTAT gathers and harmonizes scattered institutional statistical information so that information tables become compatible with each other at the country level and with data at the international level. The main objectives are to facilitate decision-maker's access to information and to bind data sources that are currently spread throughout the different institutions.

The other half of the feed balance equation involves knowledge of livestock densities, in order to calculate feed demands. Global livestock distribution databases have also been developed with FAO support. These are useful for global assessments, but the methodologies that have been employed could also be applied at more detailed national level. The Animal Health and Production Division (AGA) of the FAO commissioned the development of a global Livestock Atlas over a decade ago (FAO, 2001). It was realized that livestock and animal production statistics vary considerably from country to country, meaning that regional or continental datasets are often incomplete. Consequently, methods were developed to fill in data gaps based on distributions across environments where statistics were available. Regression techniques were used to establish statistical relationships between known livestock numbers and various environmental parameters, including those derived from satellite imagery. Livestock and cropping data were derived from country level databases supplied to FAO. These data were supplemented by more detailed surveys and censuses, where available, and a variety of novel statistical techniques were used to determine animal numbers within different ecological zones in each country.

The use of spatial distribution models has been further developed since then (FAO, 2007). These models use predictor variables such as human population density maps, distances to roads and city lights, elevation and length of growing season. Remote-sensing data inputs include NDVI, air and land surface temperature, a rainfall surrogate, humidity and potential evapotranspiration. The models are used to try to fit observed cattle densities derived from national census reports, livestock surveys and data archives. While national livestock census data are inputs into the model, the value here is in the spatial allocation of livestock data at a finer level of resolution than administrative boundaries, and in relationship to spatial distributions of GIS and remote sensing-based predictor variables. Species of livestock are mapped individually, including cattle, buffaloes, sheep, goats, poultry, and pigs and their gridded global maps are freely available (http://www.fao.org/AG/againfo/resources/en/glw/home.html). In addition, livestock can be allocated among livestock production systems using the model of Thornton *et al.* (2002; 2003). This creates an opportunity to estimate feed requirements more precisely because livestock diets for livestock in different production systems are more precise than simple species level diets.

4.7 ENVIRONMENTAL CONSIDERATIONS IN NATIONAL FEED ASSESSMENT

It would be an oversimplification to assume that livestock feed inventories sufficiently characterize the demands placed on natural resources and ecosystem services by livestock production activities. It would be negligent to recommend guidelines for carrying out livestock feed assessments without also considering these associated demands. Indeed, a broader definition of "feed balance" would consider not just the requirements of livestock for nutrition, but also the requirements for sustainable ecosystem services. The multidimensional aspects of these requirements and desirable future courses of action were examined in a study coordinated by FAO, USAID and the World Bank (Haan, Steinfeld, and Blackburn, 1996).

The assessment of LEAD (Livestock, Environment and Development) (FAO, 2006b) noted the increased demand for livestock products globally and the effects that has had on the environment. The pressures include marked expansion of land used for grazing and the advent of grain feeding and consequent demands for feed grains and arable land. It found that two antagonist trends are at play: on the one hand, production growth will further increase land demand by the sector, though at diminishing growth rates. On the other, continuous intensification will reduce the area of land used per unit of output. The relative strength of these two trends will determine the trend in total area used by livestock. It was shown that large amounts of N fertilizer are used for maize and other animal feed, especially in nitrogen-deficit areas such as North America, Southeast Asia and Western Europe. More than half of total maize production is used as feed. Other feed crops are also important consumers of chemical N fertilizer. Releases of CO_2 and other greenhouse gases were also quantified.

The multiple effects of livestock in the context of global changes in human populations, land use and climate have been reviewed many authors (Steinfield *et al.,* 2010). Han *et al.* (2010) recognized that the livestock sector is the most important global land user, and competition for land, water, fossil fuels, and climate change will be main drivers of future livestock systems. The demand for feed grains will expand to meet the continuous growth in demand for meat and milk. Many systems have shifted from grassland-based to mixed farming, and above all, to intensive production in landless systems, especially pigs and poultry. Gerber *et al.* (2010) showed that livestock are a major user of land resources, for fodder and feed production. Meat and milk production are growing faster than pasture and cropped areas due to intensification. There is particularly strong intensification and clustering in pig, poultry and dairy sectors. Reid *et al.* (2010) examined effects on biodiversity. The bigger impacts of livestock on biodiversity appear to be indirect, through deforestation to create pastures, the growing feed trade, and pollution of waters and emissions of greenhouse gases. They identified two "syndromes" by which livestock affect biodiversity. The extensive dryland syndrome occurs on moister fringes of drylands, as rangelands contract to make way for cropping and settlement, with significant impacts on biodiversity. The simplified intensive syndrome occurs where grazing is heavy and wildlife are all but excluded, and only grazing tolerant plants are able to thrive.

Feed lies at the interface of the positive and negative effects of livestock, income, livelihoods and the environment (Asner and Archer, 2010). The most profound effect of livestock on the global carbon cycle is a growing set of worldwide ecological degradation syndromes including deforestation, woody encroachment and desertification. There is also a wide range of collateral carbon flows, including losses to the atmosphere via tropical deforestation.

Feed importation to cover deficits can lead to increased environmental pressures in the way of increased stocking rates, which consequently impose increased grazing pressures on pastures, grasslands and rangelands. Although the increased feed supply that arises from importation may seem to meet animal needs, stocking rates are often raised above levels to which they would be regulated due to feed deficiencies. For example, a system that is supplemented with feeds in winter may result in higher stocking and grazing pressures on grasslands during the growing season. A second consequence of feed importation is the increase in animal waste materials and associated nutrients which must be appropriately managed to prevent nutrient accumulations in the environment, on land, in water, and through gaseous emissions (e.g. nitrous oxides). These responses may occur as a result of intra- as well as inter-national scale feed redistributions.

Blümmel *et al.* (2010) identified additional issues. One hundred times more water is needed for livestock than is used by livestock for drinking, due to use in feed production. Over 90 percent of water used in livestock agriculture is for producing feeds (FAO, 2006b). The use of rough crop by-products reduces digestive efficiency, leading to increased methane (a greenhouse gas) production. The use of roughage for feeds competes with uses for soil improvement and the leaving of crop residues in place as a part of zero tillage can be important for conservation agriculture.

Livestock can also have beneficial effects on their environments. In many areas, such as in many of the developing countries of Africa and Asia, livestock convert crop residues to manure which is then used to enrich soil fertility without the use of chemical fertilizers. A secondary benefit of crop residue use is a decreased use of grains for animal feeding. Herbivores can promote vegetation productivity under certain conditions (Frank *et al.*, 1998; McNaughton, 2001). Properly managed grazing regimes can also increase water infiltration rates and provide improved microsites for seed germination (Savory, 1988).

To summarize, livestock feed production is tied to ecosystem functioning, ecosystem services and ecological sustainability. What is produced now may or may not be sustainable, in environmental terms. What can be sustainably produced in the future, similarly, cannot be determined without consideration of environmental responses. Trade-offs with values arising from alternative land uses, such as wildlife habitat preservation, biodiversity conservation and ecosystem service provision must also be taken into consideration.

5. Guidelines for the development of National Feed Assessment Systems (NFASs) and the implementation of National Feed Assessments (NFAs)

5.1 OVERVIEW

The process of implementing a National Feed Assessment System (NFAS) occurs in three phases: 1) planning, 2) establishment and 3) updating. In the ***planning*** phase, procedures and designs are developed for the implementation of the assessment system. The ***establishment*** phase implements a fully operational system based on these procedures and designs. During the ***updating*** phase, the NFAS is sustained and improved as technology and user needs and expectations evolve. Here, the three phases of developing and maintaining a NFAS are described. The procedures are not meant to be strictly adhered to in all situations. Instead, they are suggested procedures, and they should be adapted to best fit the situation and conditions in each country or region that develops a NFAS.

The target audiences of the guidelines are members of national and regional governments and of research organizations who wish to establish a NFAS. The aim here is to provide guidance not only on technical issues but on the procedural aspects of building and institutionalizing a NFAS. It may be noted that proper understanding of the analysis and synthesis presented in the proceeding sections is a prerequisite for proper implementation of the approaches and procedures outlined here. Familiarity with the technical issues, especially related to methodologies for assessment of extensive feed resources (Chapter 16), would be helpful background information. The case studies given in Chapters 7–15 will serve as examples and aid in the establishment and updating of a NFAS. The guidelines were developed in discussions with a wide variety of subject matter experts in various aspects of feed production, livestock feed requirements and livestock production systems. Their expertise included experience in assessing livestock feed availabilities across a wide range of environments, from spatially extensive, low production systems based primarily on natural grasslands, to spatially intensive, high production, mixed crop-livestock systems.

5.2 PLANNING PHASE

5.2.1 Objectives

1. Develop a preliminary understanding of national feed resources within the context of evolving livestock systems

Before a NFAS can be developed, it is critical to develop an understanding of the feed resources in the country in question, because the NFAS will be designed to address the types of feed resources that exist there. Furthermore, the NFAS will be targeted to the types of livestock production systems that occur there. These systems will have specific needs for feed resources, and they will be based on established modes of feed acquisition and delivery. Given that livestock production systems are continuously evolving, anticipated trends in livestock systems must be anticipated in order for the NFAS to be useful into the future.

2. Plan and develop an agreed set of procedures for carrying out national feed and feed balance inventories for all types, gradations and mixtures of grassland/ rangeland-based and crop-based systems

Various methodologies, approaches and analytical tools for assessing feed availability in rangeland and crop-based livestock systems are described in Chapters 7–16 of this document. These tools are available, and they can be applied to various livestock systems as appropriate. However, the process of establishing a NFAS involves more than tool selection; for example, knowledge of institutional and organizational aspects is also important.

5.2.2 Stepwise process

1. Form a task force or working group

The first step is to establish a planning and design task force. The composition of the task force should include people with a wide variety of relevant subject matter expertise regarding livestock production systems in a broad range of environments and settings, as well as people with expertise on the procedural and organizational aspects of implementing national-scale database systems. Technical expertise will be needed in various aspects of livestock and feed production systems, agricultural statistics and spatial databases. The task force might also include stakeholders who are affected by various aspects of livestock feed production activities and feed availabilities. These could include livestock producers, government ministries, private sector representatives, NGOs and researchers or domain experts. The stakeholder group may be particularly important in rangeland and pastoral systems where feed resources are shared.

1.1 Identify and recruit task force or working group members

Key members might include:

- People with skills and knowledge in agricultural resource statistics and agricultural systems analysis;
- People with extensive knowledge of rangeland and crop-based livestock production systems, and animal nutrition;
- People with technical capabilities in GIS, remote sensing, database design, statistics, sampling and surveys;

- People with multi-disciplinary expertise, that is, with broad, large-picture, integrative, systems-level perspectives. These persons would be accustomed to working on multi-disciplinary problems in coordinated teams. For spatially extensive rangeland systems, this includes people with an understanding of pastoral systems (breeding, ecology, herd and pasture management, pasture yield measurements, disease and socio-ecology). For crop-based systems, this includes people with expertise in crop production, mixed crop-livestock systems and intensive livestock production systems;
- People from farmers' or livestock keepers' associations, and pastoral NGOs;
- People from government ministries overseeing agriculture, land use and the environment;
- People from the private sector who are involved in feed production;
- People from NGOs and research institutions who have relevant experience; and
- Proponents, including individuals who are in a position to push the implementation forward with respect to government institutions and other potential end user groups.

1.2 Identify desired outputs of the NFAS (needs assessment)

The task force should carry out an initial needs assessment to identify the types of systems and livestock feed data that already exist, and the feed data that do not exist but which are needed by decision-makers. It may be necessary to retain consultants and outside experts to participate in this assessment. A primary objective here is to identify what information will be useful to decision-makers. What are the questions that the data will provide answers to? What are the objectives of the NFAS? The assessment should consider how the information will be complied, managed, used and updated. Specific outputs should be identified and assessed in terms of information content, the utility of the data and the potential costs of producing the data. The feasibility of producing the desired data outputs could be assessed in a preliminary manner.

Desired outputs from the NFAS may include static databases, or a dynamic assessment process, or a system that has the ability to forecast future feed situations. The outputs should be identified in terms of the following:

- Format and mode of delivery (maps, documents, web sites, data bases); and
- Specific output variables to be reported; for example:
  - total feed biomass, available feed biomass, accessible feed biomass;
  - feed balance situations, number of animals that can be fed given available or accessible supplies;
  - animal products that can be produced with the available feed (milk, meat, other products);
  - anomalies in feed biomass availability, or deviations from normal;
  - seasonal, annual temporal variability and dynamics of feed availabilities;
  - projected feed availabilities into the future; and
  - uncertainty measures and statistical confidence levels.

1.3 Initial design for the inventory system

The design of the inventory system will involve processes of agreeing on terminology, approaches, methods and tools. This could occur through meetings, planning workshops, and internally and externally reviewed manuscripts. The feed resource components that will be considered must be explicitly identified. Terminologies for feed resource categories and production processes that are in currently in use are often not widely understood, precisely defined or agreed upon. The range of approaches, methods and tools is wide, and not all approaches can be expected to be suitable for the feed situations at hand. Data availabilities will vary among regions and countries. Between rangeland and crop-based systems there is a particularly wide divergence in terms of the approaches used and the types of data that are required and available. The range of approaches is demonstrated in the case studies presented in this document (Chapters 7–15). It can furthermore be expected that situations will arise in which existing approaches must be modified or expanded upon. Finally, data sources, data flows and analytic processing must all be attached to personnel who are in appropriate positions, and who have appropriate expertise. These personnel should be identified and their roles clearly stated and understood. In essence, the design of a NFAS is about systems design, in the truest sense. A system is a set of interacting components and processes. In this case they are interlinked through data flows. The processes and flows are mediated by specific personnel.

The steps to be taken in the design process include the following.

- Define the target feed and livestock systems, their typology and terminology
  - review available typologies and terminologies;
  - select and refine the typology as appropriate;
  - develop an initial glossary of terminology.
- Develop an initial design for the inventory system
  - identify overall data flows and data base designs, decision flows and specify algorithm capabilities;
  - identify existing methods, tools, algorithms, models, and data processing streams for use, and develop new methods and procedures as necessary;
  - identify participants and their roles (data sources, data users, analysts, institutional linkages, partnerships).

2. Define key classification parameters, develop a classification system, and observe commonalities among classes

The purpose of developing a livestock production system classification is to establish a framework for calculating livestock feed availabilities according to class of production system. It will improve the accuracy of the national assessment if the within-nation systems are disaggregated in such a way as to enable calculations for functionally similar types of production systems. If functionally dissimilar systems are aggregated, the feed calculations will most likely be less accurate.

2.1 Identify the key parameters that will capture the essence of various livestock production systems

The classification system will be based upon key parameters. The key parameters must be chosen with the aim of capturing key functional differences among livestock production systems. For example, functional groups of livestock production systems may be based on types of livestock, types of feed, biophysical characteristics, geographic locations and degree of integration with trade at local through international scales. It will be expedient to identify the minimum set of parameters that will have to be assembled to achieve acceptable accuracy.

2.2 Develop the livestock production system classification

The challenge here will be an acceptable, yet useful, level of aggregation. A broad classification might begin with the distinction between spatially extensive rangeland, mixed crop-livestock, and industrial/landless systems. There will be issues of what constitutes an acceptable level of aggregation. For example, crop-livestock systems might be subdivided into rice/beef systems, wheat/dairy buffalo systems and rice/pork systems, if that subdivision is based on meaningful differences in livestock feed requirements and feed sources.

2.3 Develop an increased understanding of the differences and commonalities of various livestock production systems

Develop processes for stimulating thought that results in improved understanding of a country's (and region's) livestock production systems and their dynamics and, within that broad context, the key role of feeds. Key differences and commonalities among systems will become increasingly apparent as this systems analysis is refined over time. As a result, the classification system, and the NFAS which is built upon it, will also become increasingly accurate. This process of improving understanding can be accomplished through a variety of approaches, such as networking, workshops, educational activities, and internal and external reviews.

3. Identify the methods, tools, and resources required

3.1 Assess methods and tools required in terms of technological capabilities

The methods and tools that will be used in the NFAS will be based upon existing and available technologies. The NFAS should not be designed based upon technologies that cannot be accessed. Thus, the technology that is required must be assessed in relationship to the available technological capabilities. Technological capabilities will vary among countries, among regions within countries, and among institutions within countries. For example, it can be expected that some areas might have high capabilities to use satellite/GIS data, while others will be dependent on various conventional field methodologies, and others will integrate the two approaches to varying degrees. Likewise, computation and data processing capabilities will also vary.

3.2 Assess the resources required to produce and maintain the system

The NFAS must be designed in light of the resources that will be available to produce and maintain the system. Required resources will include expertise, infrastructure, organization, personnel time and funding. Each of these must be taken into consideration. While people in-country will have general knowledge of the expertise and infrastructure that is available, it will be useful to characterize and quantify these in some way because this is related to the resource requirements. The amount of personnel time that will be required and that is available will depend on multiple factors. If the work is to be carried out within an existing institution or government unit, for example, existing personnel time may need to be freed up, and the amount will be constrained by other organizational needs. Funding resource requirements must be quantified, and sources identified. What will it cost to develop and then maintain the NFAS? Where will the funding come from?

3.3 Formulate algorithms and describe models in a preliminary or draft fashion

The NFAS will involve modelling and computation, as raw data are processed and combined to produce meaningful outputs. The exact mathematical procedures for deriving a data product must be laid out, though not necessarily fully developed in this *planning phase*. Here, the models and algorithms can be presented in a preliminary or draft fashion, and they can be more fully developed in the *establishment phase*. Models and algorithms could, for example, be presented as flow diagrams, with specific computational processes identified in terms of data inputs and derived outputs.

4. Identify data needs and sampling strategies

4.1 Identify data needs and potentially available data sources

The design of the NFAS will include specifications for data inputs and sources. Data inputs must be characterized in terms of what is being measured, how it is measured, how often it is measured and how accurate it is. At this stage, a preliminary assessment should be carried out of potential data sources and modes of delivery and access. This will likely include ground-based data on feed resources, remotely-sensed data on forage biomass, GIS data for a wide range of variables, crop production rates and harvest coefficients, and data on livestock production systems from household surveys.

4.2 Inventory current data sets, methods and tools, and conduct a needs assessment or gap analysis to identify missing data

Here, the actual work of inventorying data sets, methods and tools must be carried out in the context of a needs assessment. Inventories will likely need to assess multiple existing and potential sources for a variety of input data. The sources must be assessed in terms of ease, reliability and costs of accessing data. Similarly, existing methods and tools must be inventoried in terms of the certainty that they will be available or developed, how reliable they will be, and how costly they will be.

4.3 Develop a sampling strategy for household surveys to define a baseline

It is highly likely that many data inputs will be derived from household surveys and subsequently scaled up to villages, regions and, ultimately, the country. Consequently, a sampling scheme must be developed which includes sampling criteria for selecting representative systems within countries. The representative systems would be identified on the basis of the livestock production system classification noted above. Household surveys would provide data on livestock types and numbers, their feed types and sources, and their economics. The sampling strategy should be well designed statistically, so that case study results can be extrapolated to the larger, overall production system type.

4.4 Identify necessary resource and logistic inputs required for the data collection and sampling programmes

Data collection and sampling programmes will have been identified as above, however the resource and logistic inputs for these programmes must also be explicitly identified. Given that large areas are being covered at a national level, the need for resources could be quite significant and it is likely that resources will constrain the intensity of sampling that can actually be achieved. As such, once the resources are identified, it is likely that the sampling scheme will have to be revisited given these constraints. This is especially likely to be the case in in spatially extensive rangeland systems because large land areas with little infrastructure must be covered. In these areas, remote-sensing data will have to be used to the greatest extent possible. Remote-sensing data will be useful in both rangeland and crop-based regions, so the resources required to obtain and process these data must be carefully identified.

4.5 Develop data processing flows

Data obtained from multiple sources will need to be processed through structured databases and computational procedures. Database design is central to the NFAS. Significant effort will be required to design the structure of the databases and computational processing for transforming primary input data into derived data that are useful for assessing livestock feed availabilities at a national level. Depending on the organization of the NFAS, data may be processed centrally, or in a distributed fashion, with data coming into multiple data processing nodes distributed throughout the country, processed, and then sent on to a central, national level data processing facility.

5. Conduct feasibility studies of alternative approaches

While the NFAS design will be designed as carefully as possible, it is not guaranteed that the design will prove to be feasible once put into practice. Until the NFAS procedures are actually put to the test, it will remain uncertain as to whether they will actually prove to be feasible. Implementation of the first pass design will likely reveal areas with unanticipated capability shortfalls. Thus, it might be prudent to carry out feasibility studies of various aspects of the NFAS, which may lead to revisions in the design. The feasibilities of alternative methods, tools and means of output delivery should be considered. Feasibility studies might also include analyses of the sensitivity of outputs to the uses of alternative approaches. This could help in securing funds for establishing and maintaining the NFAS, because such studies would provide evidence that particular areas of the NFAS require additional funding to ensure that the entire NFAS is capable of providing the desired outputs.

6. Develop strategic papers

The development of strategic or white papers is an important "intermediate" step. In particular, it would be useful to develop a high-impact article addressing focused issues and problems with the development and establishment of a NFAS. Such an article would bring attention to the utility and importance of a NFAS and would highlight the challenges for its implementation. This would be useful as a focal point for the team that is working on the NFAS, for the stakeholders who stand to derive benefits from the NFAS, and for all interested parties, including the press, who would convey the story to the public and to policy-makers who have influence on national funding decisions.

7. Develop functioning regional partnerships

7.1 Identify stakeholders and partners for implementation and institutionalization

The roles of stakeholders and partners are delegated in terms of the results that are desired, and the types of inputs they are able to provide.

Stakeholders and partners are central for the implementation of the NFAS because they will undoubtedly play a variety of important roles in its ongoing operation and utilization. They may, for example, be data providers, or they may be facilitators of data sources. They will also play a role in its institutionalization. The NFAS will become an important part of the nation's livestock production system. It will become something that producers and consumers both rely upon. As such, it must have a reliable home and a dependable support system.

7.2 Analyse stakeholders and partners in terms of their desired outcomes, potential conflicts, synergies, overlaps and domains of interest

The stakeholders and partners will have varied roles, contributions, capabilities and desired outcomes. In order for these entities to function synergistically, it will be necessary to analyse their characteristics. There may be synergies, overlaps or conflicts among their potential roles and desired outcomes. These must be resolved by delegating specific roles to each entity in order to minimize conflicts and maximize synergies. In effect, this is another example of a systems analysis, in which multiple entities interact to produce a whole that is more than the mere sum of the parts.

7.3 Establish linkages to potential key partners from local communities or districts

Partners at the local community and district level will be important as data sources as well as users. The task of establishing linkages to local and district partners will be a substantial project, and will need to be identified as such. The necessary monetary, logistic and human resources must be anticipated as part of a plan to accomplish this task.

7.4 Propose and formally agree upon the partnerships

The partnerships must be formalized and agreed to in order for them to be tangible, and in order for the partners to commit and have the responsibility to follow through. The agreements will lay out the roles and responsibilities of the partner, as well as the NFAS. The NFAS will also have responsibilities to the partners. The relevant authorities or leaders will need to sign, but it may be expected that these leaders will have to seek the support of their constituencies, particularly if significant resources are involved.

8. Acquire funding for the required infrastructure (computers, labs, etc.), staffing and personnel

Funding for infrastructure and personnel will be required to establish and run the NFAS. The acquisition of funding must occur in the *planning phase*.

9. Establish or utilize existing institutional frameworks

An institutional framework must be created. The institutional framework is the backbone of the NFAS as an organization. The details of the NFAS will be built on this framework. The NFAS institutional framework may be comprised of a single NFAS organization, or it may be comprised of a coalition of organizations with diverse roles and responsibilities. It may include regional collaborations given the trans-boundary nature of many of the spatially extensive livestock production systems.

10. Develop an initial interactive data portal and web service to disseminate information arising from the planning phase

The results of the *planning phase* should be communicated as effectively as possible. The results should be made available in the internet via a web page. Secondly, a prototype data portal and web-based data service should be developed and presented or beta tested at this stage. A web site that informs users and enables data access should be central to the NFAS. At the end of the *planning phase*, users should be accessing a prototype version, providing feedback on the planned capabilities and possibly testing some of its preliminary functions using test data sets in their anticipated formats.

5.3 ESTABLISHMENT PHASE

5.3.1 Objectives

1. Implement the designs developed during the planning phase to construct a fully operational feed inventory system providing information on a regular basis

This is the primary objective of the *establishment phase*. The goal is to implement the plans and establish the first version of the NFAS. It can be anticipated that issues will arise and will need to be resolved to improve upon the first version. A stepwise process is presented below for carrying out the implementation.

2. Create inventories of livestock feed resources and conduct assessments of feed balances at local through district levels

The first outputs from the NFAS will be produced at local through district levels. The first assessments will be conducted in a select, representative subset of locales. The outputs will be evaluated and made available for internal and external review.

3. Scale up the planned approaches, methods and tools to the national level

Once the NFAS has been tested and refined in a subset of representative locales, the NFAS can be implemented throughout the country. The first national scale assessment will, in effect, be a summation of assessments from all of the regions.

5.3.2 Inputs

Success in the *establishment phase* will depend on a number of inputs, most of which will have developed as outputs from the *planning phase*.

1. The plans and designs from the planning phase, including agreed upon terminology, approaches, methods and tools

Here, the plans and designs developed during the Planning Phase will be implemented for the first time. The plans should be followed as closely as possible, but it is also likely that modifications will occur as the implementation proceeds.

2. The funding that was secured in planning phase

The NFAS cannot be implemented without sufficient funding. The *planning phase* will have provided cost estimates for the implementation, and accordingly, funding sources should have been identified. These funding sources must now be activated.

3. The institutional framework that was established in the planning phase

The institutional framework must be in place, because it will be the basis for the partnerships and collaborations necessary to implement the NFAS. This should consist of functioning regional partnerships and an interactive data portal and web service. The interactive data portal and web service will facilitate communication, and information and data sharing.

4. A technical body or organization within the framework of existing institutions

A technical body or organization will oversee the overall operation of the NFAS. While this entity will be new, it will most likely exist with the framework of existing institutions such as government ministries, national laboratories, universities and the private sector, because they will already have in place the highest level of technical expertise that is available in the country. The technical body could be the same as the Task Force identified in step 1.2 of the *planning phase*, or it could be an outgrowth of the Task Force.

5. Existing capabilities and infrastructure as identified in the planning phase

The necessary capabilities and infrastructure will have been identified in the *planning phase*, but not necessarily developed. This applies to the local as well as national level. Existing facilities can be built upon or leveraged.

6. Existing data sources that were identified in the planning phase

Data sources that were identified as already existing must be shown to be in place and operational.

7. The tools and methodologies identified and preliminarily developed in the planning phase

During the *planning phase*, tools and methodologies will have been identified and developed in preliminary or prototypic forms.

5.3.2 Stepwise process

A stepwise process is suggested here to establish a NFAS. These steps are only intended to serve as guidelines for a logical sequence of actions leading to a functional NFAS. The importance, necessity and level of investment in the suggested steps will no doubt vary among countries and among regions within countries, depending on the needs and capabilities at hand.

1. Establish and train personnel

At the outset, staff must be put in place to carry out the establishment, including the actual development, of the NFAS. Shortly thereafter, staff must be put in place to process data coming from local and regional sources, from other existing institutions and from remote-sensing platforms. Staff must be put in place that are responsible for data flow from local to national levels where local data are processed and synthesized to form the national assessment. All of these personnel may require some degree of training.

2. Develop needed technical capabilities and infrastructure beyond what exists already (Input 5)

The development of these resources must occur at the beginning of the establishment phase. It would be cost and time effective to build on or leverage existing facilities. Data handling and computational facilities and capacities will be critical. Remote-sensing hardware and software may be required. Infrastructure is necessary for carrying out household surveys and feed resource sampling. Needed resources may involve transportation, laboratory space, office space and housing.

3. Develop detailed technical specifications that are fully developed and documented

These would include specifications for:

- data types to be collected;
- data collection procedures;
- quality control procedures;
- analysis and interpretation processes;
- data production processes;
- algorithms, data flow procedures;
- database systems - including metadata;
- reporting processes; and
- interpretation of the assessment system products, in terms of when and where they can "help", and their limitations.

The full development of technical specifications based on the designs produced in the *planning phase* may occur at the outset of the *establishment phase*. Although these specifications may have been developed in the later stages of the *planning phase*, this level of detailed design requires resources which may not be put in place until the *establishment phase*. These resources include personnel, infrastructure and funding. It will be important to document the specifications so that they are standardized and replicable. Formal documentation also provides a basis for analysis, discussion and precisely targeted improvement efforts.

4. Further development of data sources

If data sources do not exist (Input 6) or if existing data sources need to be modified to suit the needs of the NFAS, then the data sources must be developed. Of course, the entire

NFAS depends on data from a wide range of sources. Sources include field data, GIS data, remote-sensing data and data being obtained by other institutions such as District Offices, and Ministries of Agriculture or Trade. Consequently, institutional arrangements may be required for data access.

5. Develop tools and methodologies

These were identified and designed in the *planning phase* (Input 7). During the *establishment phase*, they must be fully developed and tested. The tools and methodologies will be developed for data processing, computation, GIS, remote sensing and field surveys, for example. The personnel involved in tool development will be equally diverse, and are likely to be distributed among multiple teams working on various aspects of the NFAS. Since data will flow among various units, and activities must be coordinated, it will be useful if not necessary to establish cross-unit working groups.

6. Carry out the first implementation of the system to conduct a national livestock feed assessment

The first implementation of the NFAS will be carried out, no doubt in experimental mode in which the procedures are tested, evaluated and refined. Given that feed resources are dynamic, varying seasonally and annually, the assessment should include estimates of feed resources tabulated and mapped in a time series starting with a recent base year. It will be important to test the ability of the system to capture the full range of variability. The system must be shown to incorporate and process necessary data during different conditions because feed resources vary in quantity and quality.

7. Deliver and disseminate the assessment products

Products should be disseminated to stakeholders, agencies, universities and any other interested end users. An interactive data portal and web service should be resourced and activated to make the data available to any and all. Advice should be provided on the proper use of the data.

8. Validate the assessment system outputs

A variety of tests could be devised to validate estimated feed availability. Estimates should be checked against independent data sets, that is, data sets that were not used as inputs. For example, feed estimated from land use and climate data could be compared with estimates derived from market or livestock production data. When outputs are derived from remote sensing or computed from ancillary input data (e.g. precipitation, land use), there should be a methodology in place for the verification of assessment outputs against ground truth data. Validation studies should be designed using a structured sampling framework to ensure representativeness across the full range of diversity in production systems.

9. Assess the assessment system

Conduct an analysis of system capabilities and deficiencies, including a needs assessment for required improvements. Evaluate whether the system is able to produce timely and accurate data, and data that are useful to end users. Is data coverage adequate? Is it representative? Can available resources be more optimally utilized and distributed? Evaluate the efficiencies and factors that reduce efficiencies of data assimilation, processing and reporting.

10. Institutionalize the assessment system and ensure there are mechanisms to maintain the necessary infrastructure for its continued application

This step includes:

- the identification of the national implementing partner;
- the establishment of an institutionalized coordinating team. The institutional structure could be at a national level. However, regional transboundary issues prevail in spatially extensive rangelands systems and will increasingly affect crop-based systems because of increasing market utilization by livestock producers;
- the establishment of a central government budget line to support the system, along with capabilities for the necessary mobilization of resources, capital and recurrent expenditures; and
- the establishment of a regional training programme for staff who will implement the system, as well as end users who will use the outputs of the system.

11. Train stakeholders in the proper use of the data outputs

The stakeholders must be trained in the proper use of the data. This must include understanding of the intended scope and power, and conversely, the limitations of the data. The developers and participants in the NFAS would of course have the greatest understanding. However, outside analysts and consultants could develop the necessary expertise to provide this training to others.

12. Develop mechanisms to promote sharing of knowledge and experience with other countries, via an international network, or through existing regional organizations

Sharing of experience, knowledge and ideas with other countries will provide opportunities for learning. The cross-fertilization of ideas will promote creative solutions to the benefit of all. An international network of NFASs would be one way of bringing this about. The network could have a common web site or forum for exchange of information and ideas. International network meetings could be held annually or biannually. Information sharing could also take place through existing regional organizations with established memberships, for example agricultural, livestock producer and other professional organizations, scientific societies, or NGOs concerned with various stakeholder interests.

5.4 UPDATING PHASE

5.4.1 Objectives

1. Develop a process for ensuring that the NFAS is maintained and employing state-of-the-art technology and providing outputs that are relevant to current demands

The NFAS will need to be maintained, improved and updated with ongoing technological advances. This will be as much, if not more, about institutional change as it is about technologies.

2. Identify who and with what resources the system will be maintained

For the NFAS to be stable and sustainable it must have a home and a system of caretakers and overseers. This will entail the establishment of ownership. It will also entail the development of a sustainable source of income, possibly from government sources, but quite possibly also from private sources, particularly end users.

3. Ensure that the system is providing up to date, quality-assured information at relevant time scales

The NFAS must be evaluated routinely to ensure that the data it is providing is timely and accurate. The timelier the information is, the more useful and powerful it will be for decision-making. Timeliness should be evaluated in relation to the important time scales of variations in feed availability. Significant fluctuations may occur on monthly, seasonal and inter-annual time scales. In addition to climate-driven rapid changes in growing conditions, attention should be given to slowly changing variations in underlying parameters, such as land use, changes in livestock feeding practices and even societal changes.

5.4.2 Stepwise process

1. Secure funding for ongoing monitoring, system maintenance and updating

The NFAS will require a funding source to run and maintain over the long term. The utility of the results of applying the system will need to be demonstrated to potential funding sources. This, in turn, will depend on user feedback as well as results of assessments of the NFAS. It will be important to show that there is an established user base and that the NFAS outputs in some way enhance livestock production and human well-being.

2. Report the validated approaches, methods, tools and agreed terminology

Users, developers and any interested parties should be able to learn about the NFAS in as much detail as they desire. The NFAS operations must be described in a transparent way, so that all parties can understand what it is, what it does, what it requires as inputs, and what it produces as outputs. Approaches, methods and tools should be described in both simple and technical terms. Technical terminology should be clearly defined; otherwise the documentation that uses these terms will be opaque to readers.

3. Develop a process for obtaining feedback from end users, funding agencies, outside experts

The feedback process will likely entail surveys, workshops and independent reviews. An external advisory panel and/or steering committee could be established to assimilate the results of the feedback process and make recommendations for system improvement.

4. Ensure that current, state-of-the-art knowledge and institutional structures are being employed in the inventory, both in the technology behind the data acquisition, and in the interpretation and analysis of the data

Assessment system personnel must be kept up to date with the current state of the science via training, participation in conferences and research. Internal reviews could be carried out. An external advisory panel or steering committee could be established to periodically evaluate the system in this regard.

5. Conduct biannual reviews of the system, identifying strengths and weaknesses, areas where the system could be improved, and where data gaps exist

Annual or biannual reviews should be conducted to ensure that the NFAS is up to date in all respects. External reviews by experts provide valuable fresh insights and knowledge. Reviews by end users and stakeholders provide feedback on system performance related to needs and expectations. Internal reviews are valuable in that system participants have in-depth knowledge of system shortfalls and data gaps. Reviews should be constructive rather than simply being critical.

6. Refine the terminology, approaches, methods and tools

These are the central tasks involved in updating the NFAS. Terminology will need to be refined as more is learned about the factors involved in livestock feed production and availability. The increased knowledge will lead to more precise definitions of terms. The approaches, methods and tools will be refined with knowledge gained through experience and with technological advances. Experience will lead to increased understanding of what works and what does not. New ideas will arise as the NFAS provides new insights into the country's livestock feeding systems. New sources of data can be expected to come on line. New computational capabilities will be developed.

7. Develop general relationships between key livestock system parameters and observed results from monitoring sites

Over time, data from the assessments can be analysed to try to find general relationships between key production system parameters and feed availabilities among sites. Key parameters may be biophysical, organizational or economic in nature. The purpose here is to develop an increased understanding of the primary factors governing feed availability. Indeed, these scientific analyses could be carried out and published for a wide audience. The increased understanding resulting from these analyses could be used to strengthen livestock feed production systems and increase the resilience of the livestock production sector as a whole.

8. Provide ongoing training and capacity-building

Knowledgeable and skilled personnel will be required to keep the system functional into the future. Expertise will be required with respect to knowledge of livestock production systems, as well as hardware, software, databases and administration. Funding must be in place to support this training. Linkages with universities could be beneficial in this regard, because knowledge could be gained from them, and knowledge of current approaches could also be transmitted to faculty and students.

9. Ensure that the system is adapting to changing needs within the country

End users may increase in number and diversity, or they may change. The system must respond to these changing needs through the development of new approaches. This could be accomplished through recurrent needs assessments. Above all, the NFAS will continue to exist only if it is meeting the needs of its users and stakeholders.

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