Challenges for grassland science: managing research priorities

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Abstract

Production-oriented research in the second half of the 20th century made impressive contributions to technical developments which helped to meet the food requirements of an expanding world population. These developments involved increasing specialisation in land use and in food production techniques, with progressive separation between food crop production and animal production. It is now recognised that these developments have contributed to serious long-term effects on the stability of the world’s land and water resources, and on environmental hazards. Grasslands are particularly important in this spectrum of issues, in view of their dominant contribution to land use in many parts of the world, and because they occupy the nexus between the production functions and the environmental impacts of land use strategy, with implications for resource stability, biodiversity and global change. Also, they are an essential component of integrated land use systems which incorporate flexible combinations of cropping, pasture and forestry.

This paper argues the need for a re-appraisal of prioritisation and funding in research on issues of land use strategy in general, and on issues of integrated land use and grassland management in particular. There is a need to provide a stronger base for genuine inter-disciplinary research, with the emphasis on integrated land use programmes and effective coordination of production and conservation oriented objectives, and greater emphasis on a coordinated programme of large-scale, long-term, integrated land use research projects on a national or, preferably, a regional basis. Improved linkages between national and international research programmes, and closer coordination of interests between the professional bodies representing particular land use interests, are likely to be required for the effective execution and delivery of such programmes. Achievement of these objectives will require a re-evaluation of conventional research and tertiary education priorities, to encourage both a broader vision and a more informed and flexible attitude to land use issues.

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1. Introduction

The “grassland” biome potentially covers 36% of the earth’s surface (Shantz, 1954), approximately equivalent to the forest area and the area of arable
cultivation. It is important for research objectives to consider two types of grasslands: (i) the climatically determined grasslands in areas where water availability is not enough to support forests (Lauenroth, 1979), and (ii) the anthropogenically determined grasslands located in most of the temperate regions where the potential vegetation is forest and where herbaceous vegetation is maintained by domestic herbivore exploitation. Within this second type of grassland it is possible to distinguish long-term naturalized grasslands from cultivated grasslands in cropping areas. All these grasslands play an important role in the dynamics of atmosphere, hydrosphere and continental surface interactions driving global changes and environmental hazards, or adjusting to them. Grasslands therefore play a vital role in the structure and functioning of the overall landscape. They also contribute to effects on agronomic, social, environmental and economic activities at national, regional and catchment scales.

This list of attributes and processes represents a major change in emphasis in grassland science, from a specific focus on food production through most of the 20th century to a much broader concept of resource management. Developments in agricultural technology in the second half of the 20th century resulted in impressive improvements in the technical efficiency of food production in specific sectors, but also contributed to serious declines in the stability of the world’s land, water and environmental resources (Dahlberg, 1979; van der Meer and van der Putten, 1995). At the same time, there has been much less positive impact on the productivity of small-scale mixed farming systems in developing countries (Serageldin, 2001). The objective of this paper is to show that the broader aspects of grassland science are not well served by conventional research and teaching policies, and to suggest ways in which these might be adjusted to make more effective use of national and international research capability.

2. Research priorities

Grassland ecosystems are composed of inseparable and interactive components: (i) a vegetation community or communities together with a varied population of herbivores, (ii) the physical and chemical components of the soil, and (iii) a diverse soil microbial community and micro-fauna. They are subjected to herbivory (above and below ground) and mineral recycling through herbivore ingestion and excretion or through additions of fertilizers and manures. Many such systems contain legumes which contribute to cycling of N by biologically fixing N$_2$. These ecosystems are important for the quality of atmosphere and hydrosphere, for biodiversity, and as a major part of the ecology of the landscape. They can no longer be considered only as a tool for the production of animal products to meet the food demands of the human population. Grassland ecosystems have to be managed with multi-purpose objectives corresponding to the different functions assigned to grassland: environment, biodiversity, landscape ecology, and agricultural production with socio-economic outputs (Dahlberg, 1979, 1986).

In most of the European countries large land areas were formerly used in mixed farming systems where grasslands and crops interacted intimately, either spatially by exchanges of foods for animals and organic matter returns, or temporally through ley-crops rotations. Such a system provided sustainable farming in agronomic terms by ensuring long-term soil quality preservation, and also in economic terms by ensuring diversification of incomes for farmers. From the 1930s to the 1970s the importance of treating grasslands as ecosystems (in terms of both research strategy and management practice) was a constant theme in the writings of research leaders (Stapledon, 1943; Davies, 1952; McMeeken, 1952; Levy, 1970; Spedding, 1975), together with an awareness of the stabilising influence of grasslands in mixed land use systems (Davies, 1952). The requirement to increase food production, because of increasing world population and political instability, much increased the emphasis on production from grasslands (Wahlen, 1952; Whyte, 1960), and the increased use of fertilisers and technical chemicals associated in some areas with the expansion of silage maize cultivation reduced the importance of grassland in mixed farming systems. Emphasis on technical efficiency led to increasing specialisation in research and production, with spectacular effects on the productivity of grassland systems (Humphreys, 1997), but resulted in the progressive de-coupling of research on alternative or complementary land uses, on the production and conservation elements of grassland use,
and even of soil, plant and animal research in grassland studies (Wilkins, 2000). The resulting simplification and intensification of agricultural practice gave rise to problems of pollution, waste disposal and reduced biodiversity in the countryside. These are now major elements of concern in land use research.

In large parts of Europe intensification of cropping and dairy systems associated with the high prices for products has led to a specialisation of farms with the most fertile cultivated lands devoted to cereal cropping, and less fertile regions with smaller farm units devoted to intensive animal production. Each of these two systems now faces serious environmental problems, and this specialisation of land use at landscape level cannot be maintained. Because the specialisation of farming itself may be inescapable, new strategies of mixed land use by association of farm units specialised, respectively, in crop and animal production have to be promoted at landscape and regional levels in order to maintain a patchwork of cropping and grassland systems which contribute to a more sustainable agriculture. So new scientific questions emerge, concerning: (i) roles for grassland at landscape level for ecological, agronomic and environmental objectives, (ii) definition of types of grassland vegetation and management systems for optimising these roles, and (iii) the appropriate siting of grasslands within landscapes or catchments. These questions have never been addressed in the past, where research studies were concentrated upon either the field or the farm, but not at the landscape or territory level.

The concept of multifunctionality of agriculture provides a new framework for all disciplines in the sector of grassland research (Hervieu, 2002). Scientific objectives, methods of investigation and models have to be reconsidered with the aim of producing an integrative approach at a range of scales (field plot, farm, landscape, territory, etc.) where the different functions can be evaluated. The multiple functions of grassland also demand a genuinely inter-disciplinary approach to research. To achieve such objectives it is necessary to produce integrated knowledge, new concepts and new tools at the different levels of organisation of grassland agro-ecosystems: (i) the field plot where the basic biogeochemical processes are acting, (ii) the farming system where coherent management procedures are combined, (iii) the landscape where multifunctionality, interaction between different land uses and overall impact can be evaluated, and (iv) the region/nation state where socio-economic and political factors become important. Ormerod et al. (2003) emphasise the important role of ecologists in dealing with major agro-environmental questions, but the issues are much broader than this.

2.1. The role of grassland for regulating biogeochemical cycles, environmental fluxes and biodiversity at local scale

The world’s grasslands play an important role in regulation of the C cycle by storing ca. 15% of the global organic C (Tate and Ross, 1997). The mean annual primary production of grassland is similar to that of forest (Körner, 1999), and given that more than two thirds of the annual grassland biomass production is allocated to below ground structures, accumulation of deep soil organic matter layers makes an important contribution to C sequestration in most grassland ecosystems (Körner, 2002). The role of grassland in regulating the N cycle is more complex because grazing animals recover, on average, only 7% of the N supply (Grignani and Laidlaw, 2002). Nitrogen fluxes in grassland systems contribute directly to three environmental concerns: nitrate leaching, volatilisation of ammonia, and nitrous oxide emissions. Research to relate operational management decisions in grassland systems directly to their consequences to environmental fluxes have produced new methods and new concepts (Jarvis, 1999), but have not yet permitted an integrated view of the dynamics of the grassland ecosystem because: (i) the individual fluxes (nitrate leaching, N2O and NH3 emission, CO2 sequestration or emission, etc.) too often have been studied separately despite their great interdependency, and (ii) the characteristic turn-over times of the different processes involved within the system are not well known despite recent advances in stable isotope methodologies (Murphy et al., 2003). Most of these fluxes are related to soil organic matter (SOM) dynamics through soil microbial activities which couple the different processes. Moreover, the residence times of C and N within the different chemical and physical compartments of SOM are relatively long, varying from 10 to more than 100 years.
In consequence, some of the environmental outputs observed today could be the delayed consequences of changes in land use and management that occurred several years or decades ago. Similarly, changes in land use and management systems for restoring environment and biodiversity require more precise information on the time responses of the whole system: vegetation, animal, soil and microbial communities. The key scientific knowledge required is a functional and biochemical identification of the different fractions of the soil organic matter. To understand the process of SOM stabilisation, it is necessary to characterise the main biochemical compounds interacting with the soil matrix, and how C and N are protected from microbial activities. Questions on the storage of C in grassland soils and the equilibrium between C sequestration and C mineralisation are of high relevance for global change issues (Soussana et al., 2004). It is difficult to compare CO2 links in grassland and forest biomes, because there is little information on the long-term dynamics of SOM in grasslands. Modelling is the only tool for predicting long-term evolution of C in soils, but for a realistic and mechanistic representation of the dynamics of the SOM system it is necessary to invest more deeply in characterising the different functional compartments by their molecular signature (Poirier et al., 2000; Rumpel et al., 2004). There is also little information on C sequestration in deep soil horizons. The great majority of studies concern only the storage of N within the 0–30 cm soil layer, but, as demonstrated by Rumpel et al. (2002), 50% of C can be stored within deeper horizons with a higher residence time than for C stored in upper layers where microbial activity is high. This demonstrates that our knowledge on SOM and C–N cycles in grassland soil is fragmented. Due to the importance of grasslands as one of the largest biomes on the planet, increase in basic knowledge on SOM long-term dynamics must be placed at a high priority for grassland science.

Predicting plant species and community responses to grazing management is difficult (Herben and Huber-Sannwald, 2002). Diversity of grassland vegetation has long been described in terms of species number and botanical composition. Species-specific differences in life cycle phenology and growth form explain a part of this diversity (Sackville-Hamilton and Harper, 1989). More recently attempts have been made to explain diversity of grassland vegetation by functional traits (Lavorel and Garnier, 2002), either at leaf level or at root level. The advantage of such a functional approach in comparison to the botanical approach is to link vegetation diversity to the different functions the plants have to play within the ecosystem: primary production, litter quality and decomposition, competition for light and for soil resources, and interactions with herbivores. So different species, independent of their position within the phylogeny, may have similar functional traits either in terms of ecosystem effects or in terms of response to change, allowing them to be re-arranged in similar functional groups. The interactions between plants and soil micro-organisms may critically affect plant growth, plant–plant interactions and potentially plant community composition and structure (Clay, 1990). In turn, changes in plant community composition could affect microbial communities and then the soil organic matter dynamics with more or less long-term feedback (McGaig et al., 1999). So the analysis of vegetation dynamics in terms of functional groups appears to be a very powerful tool for linking changes in vegetation with biogeochemical cycles and vice versa, and also for studying effects of herbivore behaviour on vegetation dynamics and vice versa. Spatial variations in patterns of grazing and excretion, and spatio-temporal changes in abiotic and biotic environments, affect the spatial pattern and structure of vegetation (Watkinson and Ormerod, 2001; Garcia et al., in press). So studies in vegetation dynamics need to include information on temporal and spatial heterogeneity which is a dynamic component of the grazing ecosystem. For all these reasons, it appears necessary to develop integrated inter-disciplinary programmes based on networks of long-term experiments to complement and extend process-based research. With this approach:

- a wide range of grassland ecosystems (climate, soil, vegetation) would be investigated;
- contrasting managements would be applied as perturbations for long-term observation of divergent evolutionary trajectories;
- the time course for evolution of relevant state variables for vegetation, soil and populations of organisms would be monitored;
• plant–herbivore interactions and their consequences to biogeochemical cycles and vegetation dynamics would be analysed;
• environmental fluxes from and to the atmosphere and to the hydrosphere would be regularly estimated and related to changes in state variables in relation to global changes;
• key processes and interactions between compartments of the systems would be evaluated.

The outcome of such research should be common integrated databases and theoretical frameworks to explain the long-term evolution of grassland systems subjected to contrasted management programmes. A modelling approach would be necessary for integrating information and knowledge gained from this research. This would underpin scenario simulations to evaluate environmental and agricultural issues in terms of risks or benefits resulting from a range of management systems. The scientific and technological outcomes will be crucial in informing local, national and international policy makers on the role, impact and management of grassland systems for sustainable land use.

2.2. Grassland at farm and landscape scale: environmental and ecological analysis and socio-economic perspectives

The approach discussed above is only relevant at the very local scale from $10^{-1}$ to $10^3$ m$^2$ where interactions between vegetation, soil, micro-organisms, and micro-fauna occur under the constraints imposed by grazing animals. Such an approach is built on process-based research and it cannot take into account all the diversity of management programmes that grassland areas are subjected to. This “What if...” approach is not sufficient for conceiving and evaluating new management programmes dealing with environment, biodiversity and socio-economic issues. It is necessary to complement this kind of research by developing an integrated network at the level of both animal production systems and mixed grazing and cropping systems to investigate the role of different land-management programmes in resource conservation and agricultural production. The question we have to ask at this level of investigation is “What is necessary for...?” To answer this question for a series of different case studies requires the creation of new generic methodologies for conceiving and evaluating new agro-ecosystems which can satisfy multiple objectives. The achievement of compromise between the different goals (animal production, socio-economic benefits, environmental risk, biodiversity conservation or other public goods like amenity of landscape) depends on the different stakeholders and social groups involved, and several scenarios have to be investigated to provide decision support to policy makers. This suggests the need for a modelling approach for the simulation and evaluation of “virtual systems” in order to prospect a large spectrum of possibilities and to select optimum compromises between contradictory objectives.

At this level of investigation grasslands have to be considered as components of a land use system. This may be a pure grassland area like the Savanna in Africa, the Pampa and Campo in South America or the Steppe in Asia, but in most other areas in the world grassland is only a part of the land cover at the scale of landscape, and this ecosystem interacts spatially or temporally either with forest or shrub vegetation or with cropping areas. In these situations landscapes have to be explicitly described as a mosaic of soil cover with spatially distributed management programmes. The functioning of such a territorial entity can be analysed through:

• the integrated environmental fluxes at the boundaries of the system to the atmosphere and hydrosphere taking into account the spatial interactions between the different agro-ecosystems;
• biodiversity at different levels of organisation within the territory and for different populations or communities of plants, insects, birds and mammals (Wallis De Vries, 2002);
• the landscape value from a cultural and heritage point of view (Mormont, 2002).

The intensification of agriculture of Northwest Europe with the disappearance of most of the grasslands from cereal production regions was accompanied by the extinction of large number of plants, insects, birds and micro-mammals (Robinson and Sutherland, 2002). Grasslands represent an important habitat and a source of food for several protected bird species (Bretagnolle and Inchausti, in...
press; Inchausti and Bretagnolle, 2005). Such a role of grassland in biodiversity conservation can only be analysed at landscape level, and must necessarily take into account the socio-economic forces which determine the land use system and its evolution.

Such an integrated and multidisciplinary approach should help to define some options in land use and management systems to be promoted at regional scale for optimising the multifunctionality of agriculture. But this approach does not take into account the potential for socio-economic resistance to change, which needs to be identified in order to allow some evolution in land use and management systems in the direction of a more sustainable agriculture and rural economy. For this purpose the landscape has to be considered as an assembly of farmers and farm units which respond individually to their own socio-economic constraints in relation to their own goals. Multifunctionality of agriculture has to meet human demands for rural development, and socio-economic researchers have to identify and to make explicit the contradictions between the socio-economic goals of farmers and the environmental or ecological goals of the other components of society. The whole process would be aided by progress in methodology for putting a financial value on the environmental and social aspects of multifunctionality. This would facilitate the identification of optimised land use and management systems, targeting policy for sustainable agriculture, and determination of the role of grassland in such an objective.

3. Structure and funding of research

From the 1970s onwards there has been increasing concern about the impact of exploitative technology on the stability of natural resources and the sustainability of land use practices, and growing awareness of the need to balance aspects of technical and financial efficiency with concepts of resource conservation and socio-economic awareness (Dahlberg, 1979). At the same time, however, substantial changes have taken place in the structuring and funding of national and international research programmes, with increasing emphasis on market-led research and on the customer/contractor principle in research funding (Her Majesty’s Stationary Office, 1971). This emphasis has resulted in research programmes focussed increasingly on commercial advantage rather than public good (Alston et al., 1999) and in discipline-oriented rather than generic research (e.g. Mapleston and Blundell, 1995). The impact of these effects on research capability has been exacerbated by declines in national funding for agricultural research (Alston et al., 1999).

In this scenario, the increased importance of multifunctionality of grassland and the continuing dominance of grassland and grassland-based farming in many areas of the world creates new challenges to the development of optimal research structures and funding arrangements. Grassland research has for many years not fitted easily into research structures that have often had major divisions between soils, plants and animal interests. The situation is now much more complex, with the critical role of grassland for recreation, landscape, biodiversity and the quality of the soil, water and the atmosphere being increasingly emphasised in addition to its role in producing meat, milk and fibre and in sustaining rural economies. These interests are often wider than those of individual government Departments, Research Councils and Institutes. In addition, as noted earlier, key issues operate at different scales and responses may take decades for full manifestation. This produces major challenges for evolving and developing effective research programmes. In the UK, for instance, research on grassland, land use and rural communities is at the interface of the interests and responsibilities of the Biotechnology and Biological Sciences Research Council (BBSRC), the Natural Environment Research Council (NERC) and the Economics and Social Research Council (ESRC), with each of these Research Councils having a high level of autonomy. A Department for Environment, Food and Rural Affairs (Defra) was formed in 2001, with responsibilities in England and Wales across the areas of major concern for grassland and land use. A high proportion of the funding from both the Research Councils and Defra is, however, dispersed in research contracts of only 3-years duration. The time-scale required for key projects, such as those identified previously, will often be at least 10 years, more akin to that for ecological research, rather than for more controlled agricultural research or the desk studies and surveys common in social science research.
Pragmatically, the requirements for effective grassland research for the future will not drive changes in overall national research structures, and we must consider how the requirements can best be met with existing structures. In theory the requirements for research in the grassland area should be better satisfied where responsibility fits within one structure (e.g. Defra) than where the interests span a number of Departments or Research Councils. In the UK in 2001 a new collaborative programme entitled Rural Economy and Land Use (RELU) was announced which involved collaboration between BBSRC, NERC, ESRC and Defra, together with the Scottish executive, to provide funds for facilitating contacts and capacity building in interface areas, in addition to funding interdisciplinary projects (http://www.escr.ac.uk/relu/). The programme has strong central management. The initiative is to be commended, but if there is no continuing structure to focus on these interface areas, there is a serious risk that opportunities will not be taken or that the response to a need will be unduly delayed. Ideally, there should be some continuing structure controlling funds allocated by individual Research Councils and charged with the development of integrated programmes. Also, there must be realisation that for full benefits to accrue, some projects will need to have secure funding for at least a decade.

The wider issues may be taken up more readily in countries where there is a broad-based National Science Council, or equivalent body, rather than more autonomous, but sectoral, Research Councils. The Institute National de la Recherche Agronomique in France, and the Foundation for Research, Science and Technology in New Zealand, are examples of government research agencies which cover the research capability necessary for an integrated interdisciplinary approach to the role and impact of grasslands in land use and management programmes. However, despite this apparent advantage, attempts to initiate effective interdisciplinary research programmes in these areas across structural boundaries have had limited success (e.g. Lancashire, 2001). This suggests that the problems are not simply institutional, but that they also reflect research attitudes influenced by the competitive nature of much research funding, exacerbated by the “compartmentalised” nature of research administration. This points to the need for change in attitude to collaboration by both administrators and researchers, and a more determined effort to value inter-disciplinary awareness and commitment by researchers and managers alike.

These are challenges not only for research funders, but also for the whole research community. In many countries there has been little dialogue between scientists working in the agricultural, environmental and social research areas, although in Europe there has been a major increase in communication in conferences dealing with the broader issues of grassland production and conservation (Durand et al., 2002; Frame, 2002). In many circumstances competitive tendering may reduce the prospect of real collaboration, and further initiatives may need to be taken to increase the dialogue between researchers working in these different areas and build confidence that good collaborations can be established.

There is need for further consideration of ways in which international participation can make national research more effective. The case for networks of long-term experiments was made earlier. Individual experiments will, of necessity, demand considerable resources, and it is unlikely that a network could be funded by an individual country. However, where appropriate, there is potential for networks to include sites in several countries with individual sites being funded nationally. In this situation, the formation of a network has the potential to deliver tremendous added value through the pooling of information and the production of integrative models to give robust conclusions. Long-term network experiments involving different countries have rarely been carried out in the past, because of difficulty in organisation and funding. It is unlikely that there will be many occasions when countries within a zone will commit their resources to a central fund for initiating such studies. It is far more likely that they would agree to fund a single site in their own country.

Opportunities for international linkages have been provided over a period of 40 years by the International Biological Programme (1964–1974; see Worthington, 1975; Bremeyer and van Dyne, 1980) and the International Geosphere–Biosphere Programme (established in 1986, with a focus for ecosystem interests provided within it by the Global Change and Terrestrial Ecosystems programme from 1990; see Walker and Steffen, 1996). The CGIAR Institutes (http://www.cgiar.org/) provide a good framework for
creating zonal programmes for developing countries and a good focus for establishing collaborations bilaterally or multi-laterally with National Agricultural Research Institutes. There are also regional research networks set up by FAO. The European Cooperative Research Network on Pastures and Fodder Crops was established in 1976 (its activities are described in Herba. No. 13, 2003) and there is a well-established research network focussing on grassland and rangeland in the Himalayan region. However, these networks generally have funds for contact and coordination, but not for research.

In Europe the EU has become an increasingly influential research funder. Financial arrangements with other developed countries (e.g. Australia, Canada, USA, Switzerland, Norway) mean that many countries can participate in programmes initiated under the aegis of the EU. Currently the EU has a substantial focus on the environment, land use and on rural communities, all areas of importance for grassland. However, funding of individual projects rarely exceeds four years duration, and thus, with current arrangements, cannot support projects requiring a long time horizon. The EU support for ‘Centres of Excellence’ and research networks is of longer duration.

The International Grassland Congress and the International Rangeland Congress could provide fora for discussing and subsequently “parenting” network experiments, and the European Grassland Federation has Special Interest Groups that could provide a focus for the evolution of network experiments. There will be good returns for encouraging international initiatives both by researchers and by funders in order to bring such long-term network experiments to fruition.

4. Education and training

There is clearly a conflict between the increased requirement for broad-based multi-disciplinary research in the grassland and land use areas and in the progressive specialisation that has occurred in tertiary education programmes becoming increasingly focussed on specialisation at the expense of general awareness. There are doubts as to whether this will produce sufficient scientists with the vision and experience for the effective initiation, conduct, management and direction of large inter-disciplinary programmes.

It is probable that most scientists entering grassland and land use research will continue to have first degree training in a specific discipline, so we must consider how such scientists can develop to contribute most effectively to broad-based research. Courses with a focus on land use should be developed to attract a mixture of students from relevant physical, biological and social sciences. They should provide awareness for particular students of disciplines that are new to them, and real experience of working in genuinely inter-disciplinary teams to tackle particular problems and projects.

Early post-doctoral research appointments are often not conducive to developing inter-disciplinary skills. Many post-doctoral scientists work on 3-year projects and have contracts only for that length of time, maximising the incentive to focus narrowly on specific, short-term objectives, rather than contributing to broader thinking and activity. Incentives must be developed to move young researchers out of their disciplinary “comfort zone” and encourage them to develop skills important for their future development (including inter alia the requirements for benefits for all collaborators, the need to deliver to a tight and agreed timetable and the imperative of providing appropriate acknowledgement to collaborators).

The supervisor or research manager also has important responsibilities and needs the skills and experience to evolve and manage major multi-disciplinary projects. Recognition continues to be a major problem, with difficulties in developing reward promotion and tenure criteria for such work and establishing the contribution of individuals to an overall programme.

5. Conclusions

This paper has outlined the need for a re-appraisal of priorities and approaches in the structure and funding of training and research in grassland science.
It is concluded that paradigms of “hard science” and “market-led research” are most unlikely to deliver the appropriate research to meet developing land use and environmental problems. There is a need to provide a stronger basis for genuine inter-disciplinary research, with the emphasis on integrated land use programmes, effective coordination of production and conservation interests, and awareness of the underlying socio-economic and sociological dimensions. Research funding and management structures need to be changed to place more emphasis on the broader aspects of grassland science, and to provide more incentives for genuine inter-disciplinary collaboration in teaching and research.

References


