Strengths and Weaknesses of National Agricultural Research Systems: Attracting the Next Generation of Grasslands Researchers

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Abstract. Grasslands research depends heavily on the National Agricultural Research System for its R&D outcomes. Future outcomes are uncertain as funding sources have contracted and much of the expertise enters the retirement phase without a succession plan. Private funding has contributed to some extent but there remains a need for governments to continue to support those aspects that deliver public good or address market failure. The major concern expressed here is that the availability of a well-educated and trained workforce is uncertain and this may hamper grasslands from contributing sufficiently to global food security.

Keywords: Agriculture, NARS, education, CGIAR, monitoring, evaluation.

Introduction

In the 1960s and 1970s the world faced up to the poverty and hunger facing a significant proportion of the global population, which at the time was around 4 billion people. The efforts of Norman Borlaug and the Green Revolution resulted in food production increasing as the technologies and knowledge known at the time were directed to that task. The success of the Green Revolution was such that governments and the world communities turned attention to other issues and agricultural development slid down the list of priorities. The world population is now over 7 billion and projected to be over 9 billion by 2050. FAO (2012b) estimates that around 870 million people were under-nourished (in terms of dietary energy supply) in the period 2010–12; one in eight people globally. Food production will need to increase by 50 to 70% by 2050 to meet food security demands and this increase will have to be achieved through productivity gains given the limitation on global productive lands. Food production faces competition from biofuels, mining and urban sprawl for those lands, making productivity gains an even greater imperative.

These productivity gains will primarily come from agricultural research and development and the implementations of that R&D. The extent to which agricultural R&D delivers will be a function of the availability of facilities, funds to undertake the research, the extension network for dissemination of findings and a suitably educated and trained workforce at all levels from researchers to implementers to farmers.

Investment in agricultural research has been shown to provide far greater outcomes for production and development than the direct agricultural subsidies favoured by many governments (FAO 2012). Grassland systems are no exception to this, being deeply reliant on research for innovation. As rising incomes fuel the growing middle classes of emerging economies such as China, India and Brazil, greater demand for animal products is placing increased pressure on grasslands for production. This rising production demand translates into a rising research demand around the world, particularly in the agro-ecological zones found in the developing world, which traditionally have had less research focus - e.g. in C sequestration (Govaerts *et al.* 2009).

There are, however, several looming challenges to increasing the global grasslands research output. Global investment in agricultural research has been in decline since the 1980s, restricting institutional and operational capacity. Agricultural research systems and their respective institutions face ongoing administrative issues. Engagement between research and the wider agricultural sector is in need of long-overdue reform and renewal. These factors all contribute to an impending crisis in workforce availability. Attracting the next generation of grassland researchers and practitioners is critical in meeting the demands of 21st century growth and development. This review outlines some of these broader issues in agricultural research and their implications with respect to grasslands research, development and extension.

National Agricultural Research Systems

National Agricultural Research Systems (or NARS) are a means of organising agricultural research funding and implementation around national priorities. They rose to prominence in the wake of decolonisation and the growth in nation states during the post-WWII era. This can be understood within the context of wider government support for research and development (R&D) worldwide. Several NARS models exist, differentiated by their linking or separation of research and extension, the level of independence agricultural institutions enjoy from central governments and the level of centralisation within any national agricultural research organisations (NAROs) (Asopa and Beye 1997). Some NARS have independent institutes while others are associated with or integrated into universities as occurs with the US land-grant universities. The NARS benefit from links to the international

agricultural research centres (IARCs) of the CGIAR. While CGIAR is not committed to any national research agenda, as its focus is on a regional/international level, there is a spill-over of CGIAR research to NARS.

The experience of grasslands research is closely linked to that of NARS, which have faced several ongoing challenges particularly since the 1990s. The success of NARS has been variable, with research output affected by government policies and the experience of their respective research workforces. In the developed world there has been a recent trend of consolidation of institutions to reduce overhead costs, reduce duplication and retain critical mass of scientists where reductions of funding have affected research teams. This process continues to occur in Australia.

Limited monitoring and evaluation of NARS on an international level had been done by the International Service for National Agricultural Research (ISNAR), although this organisation was disbanded in 2004 (IFPRI 2007). During the 1990s ISNAR raised several issues around the operation and management of NARSs. These included a declining funding base, tensions in the priorities and demands of agricultural researchers and challenges in implementing 'monitoring and evaluation' (M&E) practices. Such challenges have compounded problems in maintaining and renewing agricultural research workforces. These issues are outlined below with a view to how they may affect grasslands research now and into the future.

Issues with NARS funding, and its effects on research

Public funding is declining

Global agricultural investment has been in a well-documented decline for three decades. This has eroded human resources, research capacity and stability within these institutions. The support for public funding of agricultural research softened in the 1980s as governments constrained public spending to reduce deficits. Strong US and UK support for such policies, along with the IMF and World Bank's Structural Adjustment Programs (SAPs), ensured these funding decreases were widespread (Byerlee and Alex 1998; Indachaba 1998; Horton and Borges-Andrade 1999; Huang *et al.* 2004). At the same time, while overseas development assistance (ODA) was increasing globally, the level of agricultural investment from aid donors remained relatively flat (FAO 2009). This trend has continued unabated, leading to an approximate 15% fall in agricultural investment as a share of total ODA since 1979 (FAO 2009). As agricultural production research is almost entirely funded through public expenditure – with 94% of public funds going to NARS (Lele *et al.* 2010) - the impact has been a decline in productivity gains. Pardey *et al.* (2012) have shown that, whilst private research funding is estimated at 35-41% of research investment, most is for off-farm activities such as food processing, leaving public funds to address the on farm productivity and environmental issues.

Countries differ in their experience of and resilience to, this decline

The source of public funding differs between countries. The breakdown of countries based on their public funding sources can be loosely characterised into three levels – developed, emerging and developing countries. Developed countries (USA, Canada, Australia, EU members) are funded through domestic spending. Emerging countries (Brazil, Indonesia, China, India) previously funded through international donors, now have much greater capacity to fund their research domestically. Developing countries (many countries in sub-Saharan Africa and Central America) remain greatly dependent on international donors (Lele *et al.* 2010). While the decline in public funding affects countries in all three levels, a generalised description masks the variation in funding environments. Some countries with the capacity to do so have increased investment in agricultural research in the early part of the 21st century (Beintema and Stads 2010). These include emerging countries such as Brazil, China and India which have experienced strong growth in research funding from the mid-1990s, partly in response to the negative experience from declines prior to that period (Horton and Borges-Andrade 1999; Huang *et al.* 2004; Beintema and Stads 2010). Of particular concern are those developing countries with high population growth where agricultural investment has sharply contracted due to: a decline in donor aid; a decline in the share of aid going to agriculture; and decline in domestic budget allocation to agriculture (FAO 2012). These countries are concentrated in South Asia, sub-Saharan Africa (SSA) and Central America (Beintema and Stads 2010; FAO 2012).

Private investment cannot replace public funding

In the context of shrinking public expenditure on agricultural research, increased private investment frequently has been seen as the solution for developed, emerging, and developing countries alike (Beintema and Stads 2010; Hu *et al.* 2011; OECD 2012; Moreddu and Poppe 2013). However, despite great enthusiasm from policy makers, analyses suggest that private investment is concentrated in only some areas of agricultural research, leaving other less profitable areas under-supported in the absence of public funding.

Numerous reports have shown that private investment tends to be concentrated in biotechnology, agro-chemicals, veterinary products, seeds and machinery (Lele *et al.* 2010; OECD 2012; Moreddu and Poppe 2013). In China, where government expenditure decreased dramatically from the mid 1980s in the expectation of increasing commercial income for agricultural research institutes, experience showed that some areas of research simply could not provide adequate levels of commercial return to attract privately sourced income or investment (Huang *et al.* 2004; Chen *et al.* 2012). Agricultural funds were subsequently increased with renewed recognition of the importance of public support for agricultural research (Huang *et al.* 2004). The Chinese experience has been substantiated in further studies. A report compiled by the Global Authors Team for the Global Conference on Agricultural Research (GCARD) found that while private investment had been increasing in many countries (including those in SSA), this investment is concentrated in commercial areas of agriculture 'where the market and institutional conditions to assure appropriate

rates of returns for their investments are present' (Lele *et al.* 2010).

The implications for grasslands research are that while private investment will be increasingly important in plant breeding programs, fertiliser use, pesticide and herbicide development, low profit areas of research (management of soil organic carbon, or salinity) and areas considered pure-science (exploratory studies in plant physiology) will receive less attention in a low-public investment environment. This suggests the need for some degree of re-orientation of public spending in favour of such areas of research. However, throughout the inevitable transition process, the current precarious funding situation has had negative impacts on human capital.

Declining overall investment is causing decline in grasslands research

The decline in public investment into agricultural research can be taken as a reasonable indicator of investment into grasslands systems research. While it would be most useful to have data detailing the investment specifically into grasslands-systems research from around the world, such data are typically unavailable. Due to grasslands systems typically being part of larger agricultural systems (livestock production systems) only approximations can be made using public figures on investments into grasslands research. This in itself represents a challenge for grassland researchers who do not have a distinctly separate discipline to promote to funding bodies. This problem has led to grasslands R&D in Australia falling in the 'cracks' between different industry groups (livestock and cropping). This paper attempts briefly to evaluate (as a case in point) the Australian grasslands research investment in the first decade of the 21st century.

In Australia, agricultural R&D is funded by levies on producers plus matching dollars from government up to a cap. The research funding is managed through specific research and development (R&D) corporations (OECD 2012). Grasslands research is primarily channelled through Meat & Livestock Australia (MLA). This levy system is championed by the World Bank as a useful mechanism for providing funding security in the long-term (Byerlee and Alex 1998). Overall MLA revenue has increased by 3.5% since 2006-07, and government funding has increased 12.9% in the same period (MLA 2011). However, funding fluctuates year by year depending on production levels within the industry and such volatility can have detrimental effects on the stability of research institutions, projects and the research workforce (Indachaba 1998). Only a portion of this R&D investment is directed towards grasslands research, with much of it being allocated to market development, product quality, animal health, animal nutrition, breeding, and farm-business management (MLA 2011). Evaluation of MLA's strategic plan (Table 1) shows very little evidence of pasture research needs and such research would appear to be low priority, even though the majority of livestock rely on grasslands, pastures and forage crops for feed. The plan suggests that funds for grasslands research are relatively small and the impact on maintaining a stable research workforce in this area must be in question.

Reduced funding threatens institutional workforce renewal

The reduced public funding for agricultural research creates significant challenges in relation to the maintenance and building of human capital. This is particularly important in relation to aid provision and developing countries but applies also to developed economies. Developing countries rely on foreign sources of research funding, in part to

Table 1. The strategic research and development plan for Meat and Livestock Australia 2010-2015 (MLA 2013).

MLA strategic imperatives 2010–2015				
1. Improving market access	2. Growing demand	3. Increasing productivity across the supply chain	4. Promoting industry integrity and sustainability	5. Increasing industry and people capability
1.1 Enhancing product integrity	2.1 Achieving consistent eating quality	3.1 Increasing productivity on farm	4.1 Ensuring sustainability and demonstrating environmental stewardship	5.1 Increasing adoption of innovation
1.2 Ensuring a whole of industry approach to maintaining and liberalising access to world meat markets	2.2 Enhancing the nutritional reputation of red meat	3.2 Increasing productivity off farm	4.2 Responding to climate change	5.2 Working with industry to attract, develop and retain world-class people
1.3 Maximising market options for producers and exporters in the livestock export trade	2.3 Developing new products	3.3 Improving supply chain and market information	4.3 Continued improvement in animal welfare	5.3 Building innovation capability
	2.4 Aggressive promotion in the domestic market	3.4 Improving animal health and biosecurity	4.4 Community communications	5.4 Supporting industry with policy research
	2.5 Aggressive promotion in export markets - beef			
	2.6 Aggressive promotion in export markets - sheep			

provide a more stable funding source than domestic sources (Indachaba 1998). Domestic funding can be subject to political instability – particularly outside of democratic systems – and economic instability. As the share of aid going to agriculture declines (FAO 2009) this decreases the level of stable funding for research in developing countries. Funding instability creates a myriad of problems for agricultural research and has a particularly negative effect on staff stability. In particular, without ample funding for adequate staff wages, or project funding, existing and prospective research staff seek occupational alternatives. A study of Nigeria's NARS, for example, by Indachaba (1998) found that organisations were systemically unstable in staff once clear disparities in staff wages were present across research sectors or relative to international wages. In the case of developed countries, funding instability is more likely to occur in the context of declining public commitment to wider agricultural R&D, or even R&D generally. This further compounds other problems with attracting people to the industry, such as declining agricultural enrolments, increasing competition between agricultural sectors and poor public perception.

A consequence of this funding contraction is that the age profile of agricultural researchers in developed economies has become older. Whilst age data are protected by privacy provisions, anecdotal estimations suggest that the average age of researchers is over 50 in Australia and the majority of the scientists in many countries are close to retirement age. It is suggested that the median age of scientists in the US NARS is close to 60 years. If such estimates are true then there are implications also for developing countries that are dependent on scientists from developed countries in aid programs to improve their agricultural productivity and sustainability. In respect of grasslands expertise, the availability of the pasture systems agronomists so prevalent a decade or two ago, is in serious decline and the following generation of such scientists is missing.

Administration of NARS and its effects on research

Communication between researchers, management and clients (producers)

The modern approach to agricultural research is the engagement and participation of producers (the clients of agricultural research) throughout the research process. This is an important component in achieving the success of NARS, ensuring that the studies are relevant to commercial practice and that producers can help in identifying problems and setting priorities for researchers. Reports in the 1990s on the evaluation of NARS identified the pressing need to integrate research priorities with the needs of producers to ensure that NARS operated efficiently. This has been consistently reiterated by the World Bank (Byerlee and Alex 1998), the IFPRI (Moreddu and Poppe 2013), the Global Forum for Agricultural Research (GFAR 2011), and the OECD (OECD 2012). More recently, the Agricultural Innovation System (AIS) model has been promoted for its incorporation of all funding, research, development, extension, production and processing stakeholders. The reasons for integrating the needs of producers with the activities of researchers are largely self-evident. By allowing producers to participate in establishing research priorities, NARS become more targeted toward areas that will be readily implemented in the respective agricultural industry. This integration can help provide greater cost benefit for governments aiming to refine spending towards areas of most impact (Byerlee and Alex 1998; Huang *et al.* 2004). This integration is part of the transition from supply-dominated to demand-driven agricultural research (OECD 2012). However, this model is not without its challenges.

In a demand-driven research system such as the AIS, researchers become more beholden to industry and producer groups, limiting their opportunities to pursue more creative and imaginative lines of enquiry. The emphasis is then on short term 'fixes' and strategic research is often disregarded. This focus on private good outcomes however, puts at risk contributions from government which exists for the purposes of common good or to overcome market failure. While Australia has been recognised for its efforts to include greater stakeholder participation in research priority-setting for agricultural research, the approach has been met with some criticism as researchers feel stifled by external control of the research focus.

The challenges presented by this topic parallel those presented by the rise in private funding for agricultural research. While allowing greater influence of industry (or producers) will allow for greater research efficiency and less public financial burden, aspects of agricultural research should not be forsaken simply due to their lack of priority within industry. There remains an important role for public funding to allow researcher input in identifying problems and addressing challenges within agricultural systems. This is particularly important in grasslands research as the need for environmental management of grasslands is paramount to ongoing sustainability.

Instituting or reforming planning, monitoring and evaluation

Monitoring and evaluation (M&E) is a critical ingredient in proper management of NARS institutions. It should be used: to help refine national research priorities (Byerlee and Alex 1998); as a tool for management of institutions and programs (Horton and Borges-Andrade 1999; Moreddu and Poppe 2013); to increase accountability (Aheto 2003); to integrate feedback from key stakeholders (Lele *et al.* 2010); and, to make the case for continued support for agricultural research (Bennett *et al.* 2012). Its expansion and development has been recommended by numerous reports into NARS (Byerlee and Alex 1998; Horton and Borges-Andrade 1999; Raina 1999; GFAR 2011) and has been achieved through compulsion for evaluation by donor agencies (OECD 2012). However, the practice of M&E, which has been adopted in order to meet donor requirements, has often been overly cumbersome on researchers and inadequately used for institutional development (Horton and Borges-Andrade 1999; Raina 1999; Sutherland and Smith 2003). Monitoring and evaluation of NARS projects and/or institutions has often focused on ex-post economic impact assessments resulting from the compulsion of donor agencies for this particular

kind of assessment (Horton and Borges-Andrade 1999; Raina 1999; Sutherland and Smith 2003; Bennett *et al.* 2012). The failure to embrace M&E more widely has been detrimental to research institutions, generating criticisms such as poor organisational management, lack of transparency, duplication of research, and an inability to articulate the benefits of agricultural research to the wider community (Raina 1999).

Reforming M&E in research institutions may provide an opportunity for grassland researchers. As public expectations of environmental management have evolved over time, there is now greater support for research that has an environmental component. Given the role of agricultural research in improving environmental management, ex-post environmental impact assessments of agricultural research should to be made available (Bennett *et al.* 2012). Grasslands researchers should strive to be leaders in this regard, articulating the importance of their work to the community through empirically-based evidence of environmental benefits as a result of grasslands research. In many countries grasslands are the largest land use. This increased use of environmental M&E of grasslands research will have the double effect of making grasslands research more appealing to a new generation of researchers, as well as helping to gain greater public funding through wider community support. For developing and emerging countries, M&E which assesses contributions to broader development goals remains critical - though much of this assessment is performed by international organisations such as the FAO (FAO 2012). Any M&E activities, however, require a specific allocation of resources, as experiences around the world have demonstrated that failure to do this simply places more strain on existing researchers – themselves often without the necessary skills for such work (Horton and Borges-Andrade 1999).

Attracting the next generation of grasslands managers and employees

The decline in real terms of the investment in agricultural R&D globally over the past several decades (Pardey *et al.* 2012) coincides with a decline in interest in agricultural education generally and particularly in higher education. Across the world, agricultural industries are experiencing a decline in the availability of appropriately trained professionals to meet the demands for future food production. Neglect of agricultural education in OECD countries has led to 'insufficient human capital' (OECD 2012). In developed countries food supply is more than ample and food does not have the emotional value, unlike in developing countries. This is due in part to community and political complacency, poor image of agriculture and lack of promotion of careers by industry. It is also a result of more competitive options, such as information technology, biotechnology and health careers, which have been promoted as exciting and 'sexy'. Yet the job market remains strong and there is now some realisation that the future depends on finding qualified people to lead the way. Recent studies have shown good employment prospects in the industry. Pratley (2012), in Australia, has shown there to be at least five jobs for every graduate in agriculture. In Canada it is suggested that there are three jobs for each graduates and there is also need for more agricultural graduates in the US and UK.

Even in developing countries, there have been changes by governments to broaden the base of the national economy away from agriculture, including active encouragement of rural populations into the cities. This is not to say that food is any less important but rather to reduce the number of people directly dependant on the small farm production and to increase efficiencies of production. In 2012, for the first time, populations in the cities of the world outnumbered populations in rural areas.

It is important to note that in many countries, the farm workforce is aging. At the same time farm size is increaseing as economies of scale are sought, particularly in developed economies. Labour saving devices are in demand except in countries endeavouring to keep rural populations employed. These changes are to some extent reducing the number of jobs on farm but the increasing sophistication of the remaining jobs necessitates a better educated and trained workforce. That in turn should assist in more rapid adoption of the outcomes of R&D. Yet in developing countries, FAO (2012b) reports that smallholders will need to play a key role if food requirements are to be met. However, the increasing sophistication of market chains will place those farmers who lack literacy and numeracy under considerable disadvantage and so provision of education in rural areas is essential.

At the same time FAO, World Bank, UNESCO and others have highlighted the issue of food security and the need to double food supply by around 2050 from the same resource base as now. The number of incidents (>30) of civil unrests in recent years because of food inadequacy emphasises the point. The concept of just growing more hectares is not an option and so productivity gains become the means of achievement.

The world is thus faced with a range of confusing, often conflicting, signals and this is being reflected in the decisions being made by students in terms of career choice (Fig. 1). The increasing exposure of the food security agenda has drawn attention to the need for more qualified people coming through the system and there are signs now that there is student response to the perceived demand even in developed economies such as US, UK, Europe and Australia.

Attracting the next generation of grasslands researchers

The impending global food crisis emphasises the need for an ongoing supply of R&D and therefore researchers. These days, researchers need doctoral qualifications. The system for attaining such qualifications was developed in mid-20th century and remains largely unchanged. While the rest of society has moved on there is still the expectation that highly intelligent people will be prepared to undergo the sacrifices of previous generations in order to qualify for a career in research. Such people are in their early to mid 20s or older and commonly have family needs. They are paid stipends on the poverty line and struggle to qualify for housing loans, stipend increments and superannuation benefits. In developed countries universities struggle to attract the top students because the conditions are

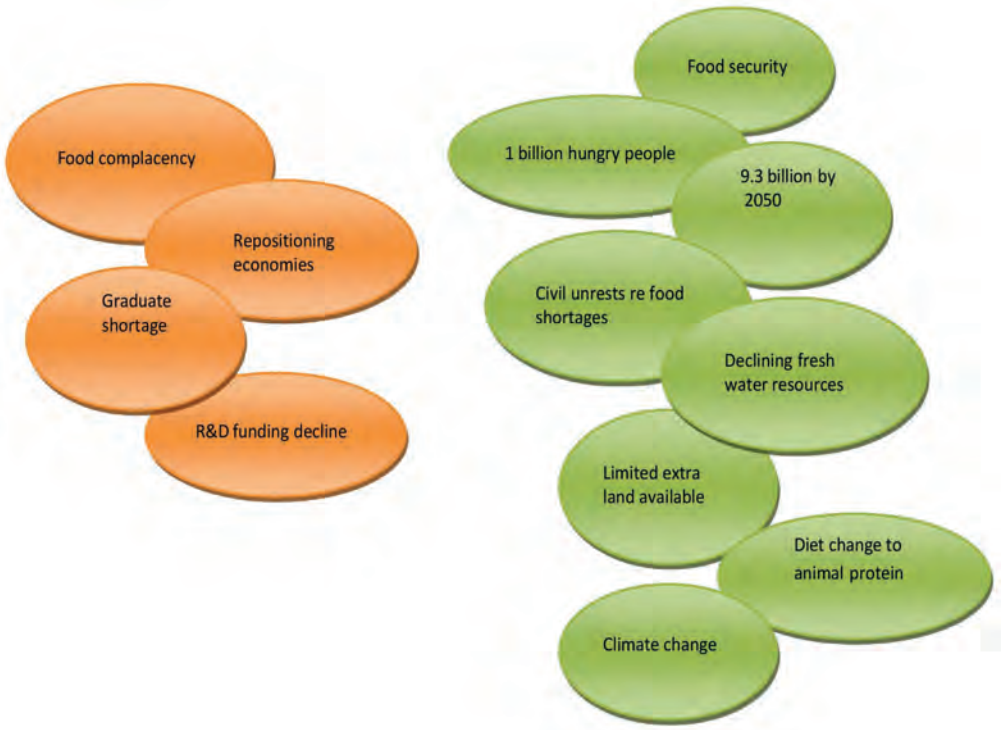

Figure 1. Mixed signals towards feeding the world

unattractive and certainly not competitive with the commercial job market. In the United States, doctorates awarded in agricultural science have remained stagnant since 1998 despite total growth in most scientific disciplines (Fiegener 2009). In Australia the conditions for employment postdoctoral are poor with limited career path in place, resulting in high attrition from the industry. This is in contrast to opportunities for first degree agriculture graduates in industry where shortage is acute.

For grasslands research training, previous comments about disappearing expertise from the sector have particular relevance here. Few universities now have specialist pasture agronomists on staff for supervision of post-graduate scholars. The same can be said for plant breeders and soil scientists, plant nutritionists and to some extent livestock husbandry experts. These are all integral disciplines to grasslands research and management. Research funding authorities, NARS and universities need to come together and address the situation before it deteriorates further.

Conclusion

This paper considers the preparedness for the agricultural research and development system to deliver the future productivity outcomes needed to sustain a global population projected to grow by more than 30% over the next four decades. Of critical importance is the infrastructure for research, the funding available to carry out the research and the workforce at all levels to conduct, extend and implement the outcomes of the R&D.

Discussion in this paper suggests that the network of NARS, supported by CGIAR activity, is unlikely to be the general limiting factor although the extent to which it is able to contribute varies from country to country.

A major concern is the availability of funds for research. This has been in decline for research in developed countries for several decades. International aid funds for agricultural research have been static, affecting the progress that can be made in those countries where need is greatest. In some of the emerging nations, R&D funding has recently increased as the demands for better food supply have increased.

Competitive grants schemes appear to be a useful mechanism for effectively targeting reduced public money. This has been widely recognised in China as having successfully reduced duplication and aligned research with national priorities (Huang *et al.* 2004; Chen *et al.* 2012). Similar systems of funding for specific projects exist in Australia, Chile, the Netherlands and New Zealand (Moreddu and Poppe 2013). Key to this competitive grants system is to contain the administrative burden on researchers.

Grasslands researchers should look to build a greater public platform to monitoring specific funding support for their discipline. Creating a distinct identity under the umbrella of existing classifications (livestock research) would ensure that adequate investment is provided to the discipline to address the ongoing management and sustainability issues. This would balance the current demand-driven research agenda and ensure that the strategic research agenda is always considered.

The expectation that private investment would increasingly assume the innovation role has been realised but only in those areas where returns on the investment can be readily obtained. This increases the importance of the need for governments to contribute in those areas where there is public good or market failure. This includes environmental management research which is essential if the private good innovations are to be successful in the longer term.

None of the above can occur, however, unless there is the availability of an appropriately educated and trained

workforce. This currently seems to be the biggest challenge. The contemporary workforce, particularly in the developed world is at or near retirement age and there has been no succession planning to replace particularly the grasslands expertise on which the world has depended over the last 30 to 40 years. The agricultural industries and the decision makers in R&D need to seriously consider the means to rebuild this expertise as all nations face the food security challenges ahead. Modernising the conditions for research scholars and early career researchers has to be part of the consideration.

References

Aheto JBK (2003) 'Performance management: a critical issue for scientific research organisations in Ghana, Yawson, Robert MSutherland, Alistair Amoa-Awua, Wisdom K, Accra, Ghana. Available at http://ssrn.com/abstract=1418242

Asopa VN, Beye, G (1997) Session 4: national agricultural research systems. *Management of agricultural research: A training manual.* Available at http://www.fao.org/docrep/W7501E/w7501e06.htm#reading [Accessed 22 April 2013].

Beintema NM, Stads GJ (2010) Public Agricultural R&D investments and capacities in developing countries. Agricultural Science & Technology Indicators, Rome. Available at http://www.asti.cgiar.org/pdf/GCARD-Back ground Note.pdf [Accessed 24 April 2013].

Bennett JW, Kelley TG, Maredia MK (2012) Integration of environmental impacts in ex-post assessments of international agricultural research: Coneptual issues, applications, and the way forward. *Research Evaluation* **21**, 216-228.

Byerlee D, Alex GE (1998) 'Strengthening national agricultural research systems: policy issues and good practice.' (World Bank: Washington, DC)

Chen KZ, Flaherty K, Zhang Y (2012) China: Recent developments in agricultural research. Agricultural Science & Technology Indicators, Rome. Available at http://www.asti.cgiar.org/pdf/China-Note.pdf [Accessed 24 April 2013].

FAO (2009) High level expert forum - how to feed the world by 2050. Available at http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Investment.pdf [Accessed 22 April 2013].

FAO (2012) Investing in agriculture for a better future. Food and Agricultural Organization of the United Nations, Rome. Available at http://www.fao.org/publications/sofa/en/.

Fiegener MK (2009) Numbers of U.S. doctorates awarded rise for sixth year, but growth slower. National Science Foundation, Arlington. Available at http://www.nsf.gov/statistics/infbrief/nsf10308/.

GFAR (2011) GCARD Synthesis Report 2010: Transforming Agricultural Research for Development. Global Forum on Agricultural Research, Rome. Available at http://www.egfar.org/documents/gcard-2010-synthesis-report [Accessed 23 April 2013].

Govaerts B, Verhulst N, Castellanos-Navarrete A, Sayre KD, Dixon J, Dendooven L (2009) Conservation Agriculture and Soil Carbon Sequestration: Between Myth and Farmer Reality. *Critical Reviews in Plant Sciences* **28**, 97-122.

Horton D, Borges-Andrade, JE (1999) Evaluation of agricultural research in Latin America and the Caribbean. *Knowledge, Technology, & Policy* **11**, 42-68.

Hu R, Liang Q, Pray C, Huang J, Jin Y (2011) Privatization, Public R&D Policy, and Private R&D Investment in China's Agriculture. *Journal of Agricultural and Resource Economics* **36**, 416-432.

Huang J, Hu R, Rozelle S (2004) China's agricultural research system and reforms: challenges and implications to the developing countries. *Asian Journal of Agriculture and Development* **1**, 1-17.

IFPRI (2007) 'IFPRI: International Service for National Agricultural Research (ISNAR) Program.' Available at http://www.isnar.cgiar.org/ [Accessed 23 April].

Indachaba FS (1998) Instability of national agricultural research systems in sub-saharan Africa: lessons from Nigeria. International Service for National Agricultural Research, The Hague.

Lele U, Pretty J, Terry E, Trigo E (2010) Transforming agricultural research for development. Global forum for agricultural research Available at http://www.egfar.org/content/transforming-agricultural-research-development-report-gcard-2010-global-author-team.

MLA (2011) Meat and Livestock Australia Annual Report 2010-2011. Meat & Livestock Australia, Sydney. Available at http://thomson.mobular.net/thomson/7/3249/4537/ [Accessed 16 May 2013].

Moreddu C, Poppe KJ (2013) Agricultural Research and Innovation Systems in Transition. *EuroChoices* **12**, 15-20.

OECD (2012) Agricultural Policy Monitoring and Evaluation 2012: OECD Countries. OECD Publishing Available at http://dx.doi.org/10.1787/agr_pol-2012-en [Accessed 23 April 2013].

Pardey PG, Alston JM, Kang CC (2012) **A**gricultural production, productivity and R&D over the past half century: An emerging new world order. International Association of Agricultural Economists (IAAE), Triennial Conference, Foz do Iguaçu, Brazil, 18-24

Pratley,J (2012) Professional Agriculture – A Case of Supply and Demand. Occasional paper No. 12.01, Australian Farm Institute, Sydney

Raina RS (1999) Patronage and Evaluation in the Indian Council of Agricultural Research. *Evaluation* **5**, 278-302.

Sutherland A, Smith DR, Yawson RM, Sutherland A, Amoa-Awua WK (Eds) (2003) 'Broadening the monitoring and evaluation of research: key concepts and aspects, Broadening monitoring and evaluation within reforming national agricultural research systems.' Accra, Ghana. Available at http://ssrn.com/abstract=1418242