Global Impacts from Improved Tropical Forages: A Meta-Analysis Revealing Overlooked Benefits and Costs, Evolving Values and New Priorities

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The XXII International Grassland Congress (Revitalising Grasslands to Sustain Our Communities) took place in Sydney, Australia from September 15 through September 19, 2013.
Proceedings Editors: David L. Michalk, Geoffrey D. Millar, Warwick B. Badgery, and Kim M. Broadfoot
Publisher: New South Wales Department of Primary Industry, Kite St., Orange New South Wales, Australia

Global impacts from improved tropical forages: A meta-analysis revealing overlooked benefits and costs, evolving values and new priorities

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Abstract. The wider use and improved performance of planted tropical forages can substantially change social, economic and environmental landscapes. By reviewing impact-related studies published in the past two decades, this paper shows how evolving development priorities have influenced the types of impacts being documented. A meta-analysis was used to examine 98 studies according to: (1) breadth of reported effects, as related to development goals of social equity, economic growth and environmental sustainability; (2) extent of effects, ranging from intermediate to longer-term impacts; and (3) measurement precision (identification, description and quantification). Impacts have been assessed for fewer than half of the documented 118 M ha with improved forages. Although Brazil accounts for 86% of the known planted area, widespread irregular reporting of technology adoption affects accuracy of global estimates. Over 80% of the impact-related studies reported economic effects, while fewer than 20% were quantitative estimates of longer-term economic impacts. Inconsistent valuation methods and assumptions prevented valid summation of total economic impacts. Social effects were reported in fewer than 60% of studies and emphasised household-level outcomes on gender and labour, with most reported effects being non-quantitative. Environmental effects were reported slightly more often than social effects, with recent increases in quantitative estimates of carbon accumulation. Few studies analysed tradeoffs. Independent reviewers conducted approximately 15% of the studies. Newer development priorities of environmental sustainability, system intensification, organisational participation and innovation capacities require broader approaches to assess impacts. Increased marketing and coordination with development and environmental organisations can generate greater demands for improved forages.

Keywords: Economics, social impacts, environmental impacts, landscapes.

Introduction

Increasing consumer demands for animal products are radically changing crop and livestock systems throughout the world (Delgado *et al.* 1999; FAO 2009). Despite reduced meat consumption per capita in some countries of Europe and the Americas (Kanerva 2011; Larsen 2012), the higher incomes of growing populations, especially in China and India, are stimulating greater global demand for and trade of livestock products (Delgado *et al.* 1999; Fu *et al.* 2012). In order to produce sufficient feed for more animals, an intensification process that improves the productivity of crop and livestock systems needs to continue – but at a more urgent pace (McDermott *et al.* 2010).

Two general strategies can intensify crop and livestock systems, namely the use of: (1) feed grain concentrates; and (2) grass and legume forages (Herrero *et al.* 2010; Bouwman *et al.* 2011), while improving animal breeds and health status can improve feed efficiency. A dramatic and steady increase in the use of feed grains has already occurred (Delgado 2005; Thornton 2010). Now, one-third of all arable land is dedicated to crop production for use as animal feed (Goodland and Anhang 2009), although there is increasing demand for feed grains for use as food and biofuel (Dixon *et al.* 2010; Taheripour *et al.* 2010). Monocrop practices can cause environmental damage (Clay 2004), such as water and air pollution from high levels of chemical fertiliser and pesticide use (Steinfeld *et al.* 2006). Furthermore, the geographic isolation of grain-producing areas from livestock areas requires significant energy inputs for transportation and nutrient supplies (Pimentel and Pimentel 2007). Consequently, total net greenhouse gas (GHG) emissions associated with grain feedlot systems are estimated to be 15% higher than emissions from intensive forage grazing systems (Pelletier *et al.* 2010). In total, the production of livestock accounts for at least 51% of global anthropogenic GHG emissions (Goodland and Anhang 2009).

Often grown on non-arable lands, grass and legume forages can generate both positive and negative changes to economic, social and environmental landscapes. In striving to estimate global impacts of improved forages, a meta-analysis approach was used to review impact-related studies from the past 2 decades associated with forage research, development, training and extension (RDTE) activities throughout the tropics, including Africa, Asia, Australia and the Americas. In addition to geography, the term global is interpreted as being comprehensive. Therefore, serving as a general framework for systematic analysis is a "triple bottom-line" concept (Elkington 1997) of social, economic and environmental changes caused by technological innovations, which has been employed by Embrapa (Avila 2001; Avila *et al*. 2008). In 2 ways, this paper is an extension of a review on adoption of tropical legumes conducted by Shelton *et al.* (2005), with: (1) the inclusion of sown grass pastures; and (2) estimates of global impacts after adoption.

Methods

RDTE innovations of improved forages within a livestock supply chain

In order to substantiate causal relations between improved forages and a potentially wide range of different impacts, a generalised forage-livestock supply chain was developed. The supply chain with 4 links: input, production, transformation and marketing (Fig. 1), can represent: (1) small-scale farmers who manage a diversity of crop and animal husbandry activities for home consumption and local markets; and (2) large-scale operations specialising in meat and/or dairy production for national and international commodity markets. Forage innovations can change both products and processes of the supply chain. Products are improved forage *germplasm*, whereas processes are affected by *innovations* of farmers working with scientists and development workers. Improved forages are rarely a stand-alone off-the-shelf technology. In most cases, the technology input requires training and extension efforts to match forages with production systems, and develop or co-develop best practices of cultivation, harvest and optimal use as a feed for a particular type of animal (Horne *et al.* 2000; Peters *et al.* 2003). Stakeholders and beneficiaries of improved forages RDTE include a diversity of participants along the supply chain, including suppliers of seeds or planting material, farmers and producer organisations, and marketers, traders and general consumers, who are affected positively by services or by negative externalities.

An array of effects on social, economic and environmental landscapes

A common distinction, *outcomes* versus *impacts*, although not clear-cut, is often used to clarify the types of effects and the times at which they occur. Adapted definitions from OECD-DAC (2002) and CGIAR (Walker *et al.* 2008) illustrate the conceptual difference: *Outcomes* (or *intermediate* or *Stage I impacts*) are the short- and medium-term effects resulting from an innovation. They represent changes in behaviour, goods and services, either on- or off-farm, which occur between the completion of a project or program and the achievement of impacts. Technology-focused studies typically assess outcomes at a geographically specific scale after adoption has occurred and there is evidence of effects, such as costs and benefits. *Impacts* (or *Stage II impacts*) are a longer-term concept. They are the positive and negative, macro-level effects on identifiable areas or population groups caused by an innovation, directly or indirectly, intended or unintended. These effects can be socio-cultural, institutional, economic, environmental, etc. Impact studies are conducted to assess 'bigger picture' impacts generated by large-scale adoption, which lead to notable changes in social, economic and environmental landscapes.

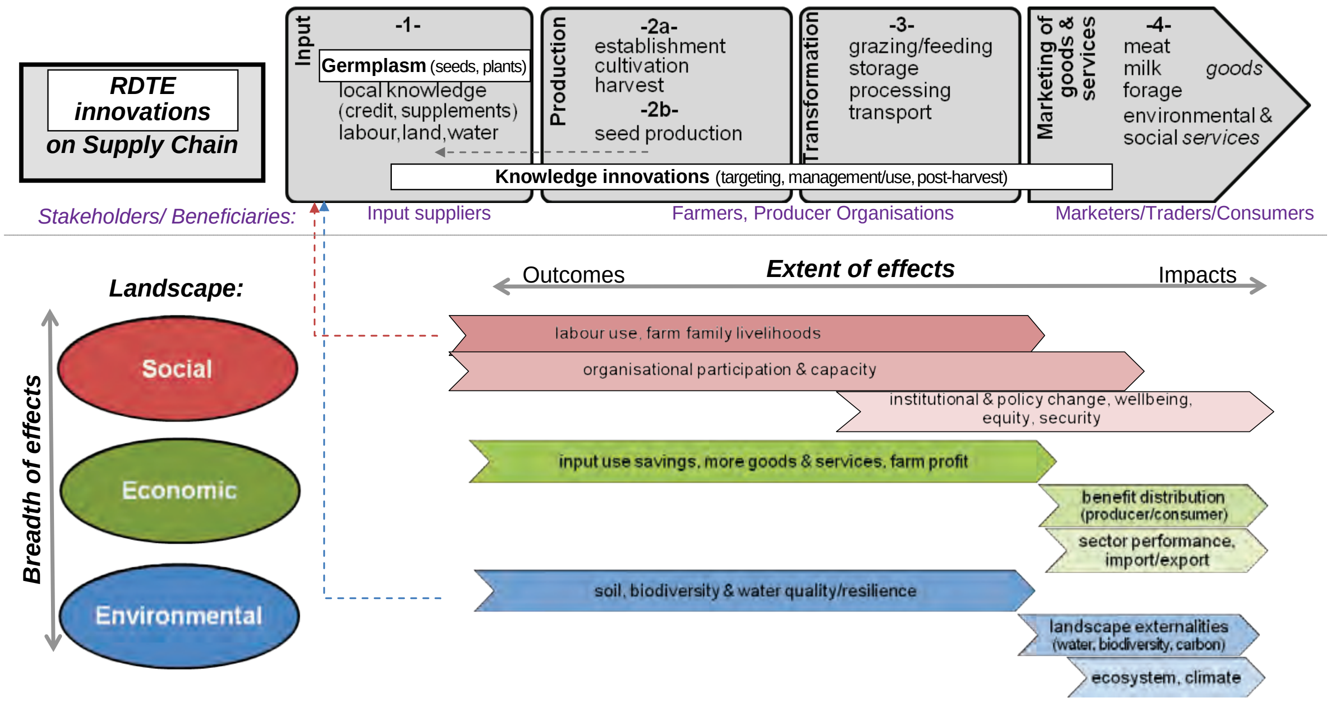

Figure 1. An array of effects on landscapes associated with RDTE innovations along a generic supply chain of improved forages

The *breadth of effects* describes the different outcomes and impacts of RDTE innovations on different landscapes. With respect to a *social landscape*, improved forages affect individuals, households, communities and nations. Intermediate outcomes include increases or decreases in labour use of family members. Other possible social effects include enhanced farmer participation in producer or community organizations. Fostered farmer participation in, and capacity building of, organizations along a supply chain can lead to significant institutional change, with greater influence in policy decisions that can ultimately result in improved well-being and equity. An *economic landscape* also changes in many ways as a result of forage RDTE innovations. At the farm level, input use savings, or factor efficiencies, generate different outcomes, such as reduced requirements for labour, rainfall/water or fertilizer. Also, cultivation of improved forages can lead to greater productivity, typically measured in yield of biomass, energy or protein per unit area. Nevertheless, forages are an intermediate product and typically used for other purposes such as animal feed. Improved forages can enhance efficiencies of product transformation that result in higher farm gross and net revenues (profits). At international scale, economic impacts of improved forages can include changes to the performance of a livestock subsector with respect to its enhanced competitivity and comparative advantage. Such analyses often include examination of government policy interventions (*e.g*., subsidies, taxes and tariffs on inputs, outputs, imports and exports) on sector performance.

Effects of improved forages on the *environmental landscape* are often both positive and negative, and can lead to tradeoffs with social and economic objectives. On-farm, positive outcomes include better ability to withstand pests, diseases, flooding and drought. Improved forages can also cover soils faster and more completely, thereby reducing erosion and weed infestations. Deep root structures can access water during dry seasons and store carbon in soils. Legume forages, in particular, fix nitrogen in soils, thereby improving soil health and fertility. Such on-farm performance improvements can generate potentially significant benefits by preventing losses of biomass production and improving overall farm resilience to weather shocks. At farm and landscape levels, negative impacts of improved forages include soil acidification and invasiveness of some species. Other impacts can arise from a cumulative effect of better farm productivity at larger scales including changes to downstream water flows, quality and sedimentation. Whether off-farm environmental effects are beneficial or detrimental depend on specific site contexts and management practices, thereby posing challenges to accurate measurement of impacts.

Methods

A meta-analysis approach was used to examine diverse effects from improved forage germplasm and associated knowledge-sharing innovations. Although the task of identifying studies for inclusion could be considered simple, identification requires a clear operational definition of the phenomenon being examined (Rudel 2008). The process of reviewing the studies enabled the comprehensive specification of effects on landscapes (Fig. 1), which, in turn, served as the analytical framework for case selection. Via web-based literature searches, reviews of references within papers, and communications with forages experts, a pool of over 170 studies was collected from which 98 were selected for use within the sample. Many disqualified studies were characterizations of existing forage/livestock systems or were studies of farm trials or adoption - without any description or quantification of impact. Although the search was conducted in four languages, most studies were written in English, with four in Spanish, one in Portuguese and none in French.

Many impacts remain undocumented within the literature due to financial, technical and other restrictions that often prevent a comprehensive assessment of forage innovations. In order to minimize publication bias (Rothstein *et al.* 2005) that would reduce estimates of global impacts, the dataset was expanded to include “non-impact” studies such as project reports and other documents that also describe impacts. Also, for countries where only information on technology adoption or productivity increases was available, authors were contacted in effort to obtain grey literature of impacts. Although the sample represents a diversity of countries from tropical Africa, Asia, Australia and Latin America a paucity of the smaller, less-populous countries became evident.

Keywords pertaining to the types of effects, along with synonyms, were used to identify their presence or absence. Reported effects within a study sometimes represented more than one location or type forage. Therefore, reported effects were larger than number of studies. Review of the units of analysis and associated text permitted the determination of: (1) outcomes versus impacts; and (2) the measurements precision used within the analysis. Categories of measurement precision represented three levels: (1) simple mention or identification; (2) narrative or qualitative description; or (3) quantitative analysis. All economic estimates were adjusted according to inflation and are reported in 2005 US$.

Results and discussion

Approximately 118 million ha planted with improved forages has been documented, with Brazil accounting for 86% of the known planted area (IGBE 2007; Landers 2007; CIAT, 2013). Nevertheless in all countries, the irregular reporting of technology adoption and incomplete analysis of associated impacts (<50% of adopted area) distort the accuracy of global adoption and impact estimates.

Nearly 80% of the impact-related studies were published between 1999 and 2013. Within the sample, over 200 different types of effects were reported. Nevertheless, approximately 2/3 of the effects were intermediate, not longer-term, larger-scale impacts. Although economic effects were most frequently reported, less than 20% of all reported effects were quantified economic impacts. Environmental and social impacts were even less frequently quantified, with 7% and 2% respectively of the total type of effects reported (Table 1). More than 34% of reported effects were mentions or brief descriptions of change. Although such results were not quantitative, the information provided aids in better understanding the

Table 1. Reported effects (% of total), per type and extent of effect and measurement precision.

	Outcomes			Impacts		
	mentioned	*described*	*quantified*	*mentioned*	*described*	*quantified*
Social	3	10	10	1	3	2
Econ	2	3	16	0	0	19
Env	8	4	8	2	4	7

global impacts of improved forages.

Earlier studies tended to report outcomes rather than impacts. The progression of extending analysis to longer-term impacts could be a consequence of increasing scientific capacity, availability of new assessment methods and policy priorities to understand larger-scale effects. In the face of multiple confounding factors, which hinder the substantiation of cause-and-effect arguments, studies are increasingly using mixed quantitative and qualitative methods such as detailed narratives or diagrams of causal impact pathways, which typically acknowledge a broader array of effects (*e.g*., Cramb 2000; Patak *et al.* 2004; Connell *et al*. 2010, Ayele *et al.* 2012). Nevertheless, less than 15% of studies were conducted independently of personnel affiliated with the program or project. Limited collaboration with evaluation experts and organisations may have prevented the use of new assessment methods and approaches.

Analyses of economic impacts employed inconsistent estimation methods and assumptions, thereby preventing a valid summation of total economic benefit of the studies. Review of economic impacts reported within the sample reveal nine critical methodological shortcomings, many of which have been highlighted in other meta analyses of economic benefits (Raitzer 2003; Raitzer and Linder 2005; McClintock and Griffith 2010). One, estimates were based on the results employing different estimation methods, which include economic surplus models, cost-benefit accounting or unsubstantiated expert opinion. Two, estimates economic impacts represented different periods of time. Benefits were reported as annual estimates or the net present value (NPV) that represented a different multi-year periods. Moreover, different rates (5 and 10%) were used to discount the future value of benefits, thereby substantially affecting the magnitude of NPV estimates. Three, economic impacts were reported in terms of gross economic benefit or net of costs. Four, costs were inconsistently defined across the studies. Reported costs included R&D, T&E and adoption. R&D and T&E costs largely pertain to public sector organizations that finance such activities (though private companies produce and market seeds). Estimation of these costs often requires the use of numerous assumptions regarding staff time and other investments attributable to an improved forage. Meanwhile, farmers face a variety of technology adoption costs. Such private costs include those pertaining to: (1) working capital associated with planting improved forages and purchasing more animals; (2) capital investments such as infrastructure (*e.g*. corrals, barns, fencing); and (3) opportunity costs of land and labour. Opportunity costs of land could be significant if land previously produced crops or generated positive environmental externalities (*e.g.* biodiversity, carbon storage, water flow regulation). Labour costs of innovation, such as those related to advancing, acquiring, adapting and/or sharing knowledge were not included. While some studies discussed and analysed a portion of these costs, no study addressed all potential costs. Five, descriptions and types of data on technology adoption were inconsistent. Studies exhibited wide variation with respect to geographic scope, intensity of use per farm, and duration of use. More than 50% of studies reporting economic impacts did not use empirical data to base estimates of technology adoption, but instead depended solely on experts opinion (Table 2). Six, transparency in the documentation of analytical methods was not consistent across the studies. Seven, in the face of inherent uncertainty of costs, adoption and discount rates, sensitivity analyses of changes in parameter estimates were rarely performed. Eight, despite many economic estimates representing largely ex-ante, or a combination ex-post and ex-ante, time horizons, scenario analyses were not included to examine the effects of assumptions employed to represent future conditions (*e.g*., yield improvement, input and output prices, climate change).

In addition, economic analyses of substitute inputs, such as feed grain concentrates, were not conducted. Nine, economic analyses emphasised production performance with little acknowledgement or discussion of the economic values derived from decreased risk of crop, food and income failures. Furthermore, benefits associated with enhanced environmental conditions/resilience and improved social wellbeing/security remain largely unrecognized.

Despite the biases and limitations inherent to the sample, large scale economic impacts from grasses were evident in Latin America (Table 2). In contrast, impacts from grasses and legumes were more evenly reported from Africa, Southeast Asia and Australia. Consequently, the traditional biological distinction between grasses and legumes was replaced with a producer/market contrast of smallholder local market versus largeholder national /international market. The economic benefits from new spittlebug resistant *Brachiarias* in Latin America were the largest reported (Rivas and Holmann 2004; Paim *et al.* 2009). Whereas, benefits resulting from *Stylosanthes* varieties resistant to anthracnose disease were less substantial, perhaps due to less rigorous adoption and economic impact analysis. Other large-scale economic impacts from grasses were realized in Australia (Chudleigh 1996). Economic benefits from some forages species were estimated in different years. Economic benefits of *Stylosanthes* and *Leucaena* reported in Australia point to expanding use and economic impact (Rains 2005; Shelton and Dalzell 2007). For *Stylosanthes* in Brazil, the estimated value of nitrogen in soils exceeded the value as a feed (Paim *et al.* 2009). Despite substantial investment and

Table 2. Summary information: economic impacts of improved forages.

Country/ region	NPV (million US$ 2005)	Annual (million US$ 2005)	Forage(s)	Area x1000 ha	First author, publication date	Adoption data
Smallholder / local market						
W Africa	19 (96)[a]		*Stylosanthes guianensis S. guianensis, S. hamata*	19 (52)	Elbasha 1999	Statistics & survey
W Africa	46[a]		*Stylosanthes spp. Centrosema pascuorum, Aeschynomene hystrix*	32	Tarawali 2005	Stats & survey
W Africa	491[a]		*Vigna unguiculata*	1400	Kristjanson 2002	Stats, survey & modeling
Indonesia	1010		*Pennisetum, Gliricidia Leucaena, Sesbania*	n.r.	Martin 2010	1/3 value of future cattle sales
Kenya		7.9	*Calliandra calothyrsus*	~82	Place 2009	Survey
Uganda, N.Tanzania, Rwanda		2.2	*Calliandra calothyrsus*	~103	Place 2009	Survey
India		?	*Stylosanthes spp*	>250	Ramesh 2005	Experts
Thailand		0.75	*Stylosanthes*	>300	Phaikaew 2005	Experts
China		22	*Stylosanthes*	>200	Guadao 2005	Experts
Largeholder/ national, international markets						
Australia*	1387	37[b]	*Cenchrus ciliaris*	6915	Chudleigh 1996	Stats, experts & extrapolation
Australia*	244	7[b]	*Stylosanthes spp*	1154	Chudleigh 1996	Stats, exp & extrap
Australia*	659	17[b]	All improved pastures	7772	Chudleigh 1996	Stats, exp & extrap
C America, Mexico	1790	243[c]	*Brachiaria spp*	3287	Holmann 2004	Seed sales
Colombia, C. America, Mexico	4413	497	*Brachiaria spp*	4429	Rivas 2004	Seed sales
Mexico		41[c]	Improved forages & technology	n.r.	Espinoza 2003	Experts
Australia		~0.9	*Clitoria ternatea*	100	Conway 2005	Experts
Australia		2	*Centrosema pascuorum*	5	Cameron 2005	Experts
Australia		22.4	*Stylosanthes scabra, S. hamata*	1500	Rains 2005	Experts
Australia		15	*Stylosanthes scabra, S. hamata*	1000	Noble 2000	Stats, expert
Australia		15	*Leucaena leucocephala*	100	Mullen 2005	Expert
Australia		69	*Leucaena leucocephala*	150	Shelton 2007	% cattle offtake
Brazil	6269	1826[d]	*Brachiaria brizantha* cv. Marandu	23621	Paim 2009	Seed sales
Brazil		13.5[d]	Seed production	n.r.	Paim 2009	Seed sales
Brazil	5749	772[d]	*Panicum maximum* cv. Tanzania	4746	Paim 2009	Seed sales
Brazil	4499	1640[d]	*Panicum maximum* cv. Mombasa	10074	Paim 2009	Seed sales
Brazil	7	1.7	*Stylosanthes capitata, S. macrocephala*	200	Paim 2009	Seed sales
Brazil		33	*Pueraria phaseloides*	480	Valentim 2005	Expert
Brazil		4	*Arachis pintoi*	65	Valentim 2005	Expert
USA		7	*Arachis glabrata*	8	Williams 2005	Expert
USA		2.4[e]	*Aeschynomene americana*	65	Sollenberger 2005	Expert
USA		0.5[e]	*Desmodium heterocarpon*	14	Sollenberger 2005	Expert

[a] net costs of RDTE and adoption (establishment and additional cattle); [b] The break-even cost to prevent negative impact from forage plants, being annual cost to reduce NPV of benefits to zero; [c] 50% adoption rate assumption; [d] estimate of final year of seed sale data (2006); [e] estimates from Sheldon *et al.* 2005.

reported adoption in Southeast Asia (Guadao and Chakraborty 2005; Phaikew *et al.* 2005; Stur *et al.* 2007) and South Asia (Ramesh *et al.* 2005), only one empirical analysis of economic impact has been conducted in Indonesia (Martin 2010).

Inquiry into environmental benefits of improved forages increased in sophistication from their on-farm productivity changes to also include quantitative inquiry into tradeoffs between the use of forage legumes as a feed or green manure (Quintero *et al.* 2009a), direct seeding of crop-pasture rotations (Embrapa 2004), conservation agriculture (Kassam *et al*. 2010 Landers 2007; Silici 2010) and the co-benefits associated with integrated management of striga weeds, insect pests and soil health (Khan *et al.* 2011). Analyses also expanded to examine off-farm impacts associated with environmental services of reduced erosion and downstream sedimentation and pollution (Quintero *et al.* 2006, 2009b; White *et al.* 2007) and carbon and biodiversity benefits from silvopastoral systems (Pagiola *et al.* 2007). Each of these analyses examined the effects of comprehensive farm management, which typically contain a component of improved forages. In addition, reporting of carbon storage and associated climate change mitigation continues to expand from analyses of deep rooting *Brachiaria* grasses in Colombia (Fisher *et al.* 1994) to Brazil (Pinto *et al.* 1996; Tarre *et al.* 2001; Fisher *et al.* 2007; Brunet *et al.* 2005; Marchao *et al.* 2009; Tonucci *et al.* 2011), *Leucaena* Australia (Sheldon and Dalzell 2007) and grasslands in Latin America (t'Mannetje *et al.* 2008) and worldwide (FAO 2010). Attributing some off-farm environmental impacts to improved forages can be tenuous connection. For example, the adoption of improved forages cannot be considered a sufficient condition to avoiding deforestation. Other factors affecting the conservation of forests, such as local and national policies and their enforcement are also needed for forest protection. Nevertheless, the contribution of improved forages to intensification and land/forest saving can be considered a necessary condition. Serving as a logical narrative to substantiate a causal technology-forest link is that intensification enables similar quantities of livestock products to be produced on smaller land areas (White *et al.* 2001; Kaimowitz and Angelsen 2008; Ewers *et al.* 2009; Connell *et al.* 2010; Cohn *et al.* 2011). Despite the challenges of attributing "saved" areas to improved forages, the magnitude, importance and value of ecosystems services from these original land uses can be substantial. Even without including emissions from land use change, estimates of a plausible mitigation potential of livestock and pasture management options in mixed and rangeland-based production systems of the tropics could contribute approximately 4% of global agricultural GHG mitigation with a corresponding economic value of approximately $1.3 billion per year at a price of $20 per ton CO_2 (Thornton and Herrero *et al.* 2010)The most-commonly reported social impacts were at the family level with savings in family labour, especially that of women and children (*e.g.*, Ahmed 2012; Connell *et al.* 2010; Maxwell *et al.* 2012), and family nutrition and food security (Kassa *et al.* 2000). At the organisational level, social benefits included increased farmer and stakeholder participation and capacities along links of the supply chain (Ayele *et al.* 2013; Stur *et al.* 2013; Shiferaw *et al*. 2011). Measurement of larger social impacts remains difficult since many factors are likely to affect the functioning and status of political processes, national security, equity and wellbeing. Although estimates of economic benefits were dis-aggregated according to wealth/poverty by Rivas and Holmann (2004) and show substantial purchasing power benefits accruing to the less-wealthy consumers of animal products, notions of development and associated social benefit are often considered to contain aspect of increased local capacity to achieve impact – not merely the results of technological change. In order to address measurement and valuation challenges that come with broader definitions of social benefit, quantitative analytical methods are being combined or complemented with qualitative methods. Such analyses are part of a new-breed of impact analyses that increasingly recognize processes of social change along entire forage/livestock supply chain, from inputs and cultivation to feeding and marketing (Connell *et al.* 2010; Shiferaw *et al*. 2011; Ayele *et al*. 2012; Stur *et al.* 2013).

Conclusion

Although past claims that forage adoption, especially of legumes, as being relatively poor across all tropical farming systems (Squires *et al*. 1992; Thomas and Sumberg 1995; Pengelly *et al*. 2003) may continue to echo, improved grass and legume forages have generated substantial impacts across uncountable social, economic and environmental landscapes. A broadening to include outcomes enabled a larger diversity of impacts to be identified and described. Nevertheless, the sample was likely biased with a tendency to report only larger, relatively homogenous impacts that are easier to measure. Consequently, impacts highlighted above are conservative and represent a fraction of the total.

Impacts evaluation continues to evolve in attempt to better understand aid and development processes (Sterne *et al.* 2012). The systematic meta-analysis of impact-related documents points to continuing efforts to comprehend cause-and-effect relationships between RDTE activities and impacts. Such an evolution corresponds to three general prescriptive approaches associated with theory of evaluation that focus on: (1) methods and experimental design; (2) human and social values used to judge evaluation results; or (3) users of the information (Alkin 2012). One, the sample of impact-related documents reflects many advances of forages RDTE affecting the performance of multiple links along livestock supply chain. Impact assessments are developing better methods to measure and value both benefits and costs in terms of social, economic and environmental landscapes. In effort to overcome an apparent bias towards examining economic impacts, more analyses are recognizing and attempting to evaluate environmental and social benefits. Two, inquiries into the effectiveness of forages RDTE increasingly includes stakeholder narratives within project and program evaluations. Such contextual perspectives also bolster the strength of causal arguments of quantitative impact analyses. Three, the use of impact information is expanding to affect different types of policy decisions - ranging from local to global development efforts. Although the direct reach of impact studies may be limited, improved internet access to studies can help inform policy debate and subsequent decisions. Furthermore, enhanced inquiry into informational demands and associated targeting of communications regarding the benefits of improved forages RDTE can help meet the specific priorities and needs of diverse potential investors, ranging from farmers to international organizations. For example, as negotiations for climate change mitigation clarify the rules-of-the-game, economic compensation for carbon accumulation of improved crop-livestock systems may enable additional social and environmental objectives to be met. With the substantiation of multiple benefits of improved forages, greater levels of investment can be motivated not only from traditional public sector agencies and philanthropic foundations, but also the private sector and non-government organizations.

Acknowledgements

The authors appreciate the insightful comments received from Bob Clements, responses from the case study authors and the financial support from ACIAR.

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