CSIRO PUBLISHING
www.publish.csiro.au/journals/trj *The Rangeland Journal*, 2009, **31**, 223–230

# Enabling the uptake of livestock–water productivity interventions in the crop–livestock systems of sub-Saharan Africa

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**Abstract.** Livestock–water productivity (LWP) refers to a set of innovations that could contribute towards reducing the amount of water needed per unit of output generated. But what does it take to get these ideas adopted by livestock keepers in crop–livestock systems? In this paper, we treat LWP as an innovation, and consider in what ways it may be introduced and/or developed among the crop–livestock agricultural systems by drawing on successful examples of change. In the first part of this paper, we introduce relevant tenets of the innovation systems literature, and introduce a three-component conceptual framework for the adoption of LWP technologies. In the second part, we describe three successful cases of resources use change. In the final section, we identify what we consider to be necessary components in successful change, and relate these to LWP. We argue that, in the under-regulated crop–livestock systems of eastern Africa, key areas for focus include social institutions, political systems, gender and leadership.

**Additional keywords:** conceptual framework, innovation systems, institutions, leadership.

## Introduction: livestock and water

Recent discussion on water productivity (WP) in agriculture highlights livestock as a key area for WP improvement (cf. Molden 2007). Peden *et al*. (2007) define livestock–water productivity (LWP) as the ratio of net beneficial livestock-related products and services to the water depleted in producing them. The concept acknowledges the importance of competing uses of water but focuses on livestock-water interaction. Livestock water productivity is a systems concept, and obtaining LWP success is unlikely to occur unless it is understood as a system-wide change.

There are many ways in which livestock affect WP across a landscape, but the two key areas are through the feed that they consume, and the damage they can potentially cause to a landscape's hydrology. About 450 $m^3$ of water is required annually to produce the feed needed to maintain one Tropical Livestock Unit (TLU: measured at 250 kg liveweight). When animals are growing, working, stressed or lactating, they use even more. Water used to produce feed is estimated at 500 billion $m^3$ or more per year for maintenance. Total water needed may be more than double this amount, with drinking water less than 2% of that required for feed production (Peden *et al*. 2007). Feeds, however, have highly variable water productivity, ranging from 0.5 kg above-ground dry matter per $m^3$ water (US grasslands on 300 mm annual rainfall) to 8 kg per $m^3$ (irrigated forage sorghum, Sudan) (Peden *et al*. 2007). Indeed, the complexity and diversity of livestock production systems create great uncertainty regarding the actual amounts of water used by livestock (Peden *et al*. 2009).

The impact of high livestock densities on a landscape are also thought to affect its hydrology profoundly, causing erosion of varying intensity, widespread depletion to vegetative cover and other damage (the linear relationship between stocking densities and erosion, 'desertification' and other landscape damage is frequently contested – see, for example, Behnke and Scoones 1993; Sullivan 1999; Rowntree *et al*. 2004). Again, there is immense variability in how and where high livestock densities affect landscape hydrology, but a key area for concern is damage to landscapes surrounding livestock water points, and underutilised fodder in landscapes away from such water sources.

These issues matter because as populations in developing countries grow wealthier, the proportion of animal products in their diets tends to increase (de Fraiture *et al*. 2007). In sub-Saharan Africa, consumption is projected to grow at 3.2% per year between 1997 and 2020 (Peden *et al*. 2007). As a result, water demands by the sector will also increase, and it makes sense to consider ways in which livestock water productivity can be improved.


10.1071/RJ09008 1036-9872/09/020223

Systems designed to improve LWP must be implemented at landscape scales if they are to have any discernible impact on water productivity. Livestock water productivity improvements suggest complementary improvements to farming systems and soil and land management, and are therefore integrated solutions to water productivity problems. Improving LWP implies both institutional innovation (for example, changing the way in which livestock are grazed) and technical (for example, well spaced watering places).

This paper focuses on the mixed crop–livestock systems of sub-Saharan Africa. These are defined as those in which crop and livestock production activities are managed by the same economic entity, such as a household, with animal inputs (for example, manure or draft power) being used in crop production and crop inputs (for example, residues or forage) being used in livestock production (Williams *et al*. 2000). In this paper, we treat LWP as an innovation, and consider in what ways it may be introduced and/or developed among the crop–livestock agricultural systems by drawing on successful examples of change from this area. In the first part of this paper, we introduce relevant tenets of the innovation systems literature, and introduce a three-component conceptual framework for the adoption of LWP technologies. In the second part of the paper, we describe three successful cases of land use change. In the final section, we identify what we consider to be necessary components in successful change, and relate these to LWP.

## Innovations for improving LWP

Innovations are novel ways of doing things better or differently, often by quantum leaps rather than incremental gains (Perrin 2002). In this sense, *all* innovation (be it technical or institutional) implies behavioural change. Innovation is often viewed as a linear process, the so-called 'pipeline model', in which research generates solutions that are then more or less seamlessly adopted by the target population for which they are designed (cf. Douthwaite 2002; Biggs 2007). Generally speaking, however, innovation is not linear, but based on what Raymond (2001) refers to as a 'complex adaptive system' (CAS). Here, a 'babbling multitude' of people with different agendas and opinions somehow create coherent and stable programs. In a CAS, 'agents' (i.e. someone with agency – the capacity to change something) use strategies in their interactions with other agents and with artefacts. Agents will evaluate the subsequent results of these interactions and so choose to copy strategies or artefacts, or recombine or invent new ones. This evolutionary process of selecting what works, copying, recombining and inventing constantly introduces novelty. Under a CAS perspective, LWP can be seen as an emergent property resulting from the interaction of agents, strategies and artefacts. Insofar as communities in the developing world are concerned, successful innovation tends to be indigenous (i.e. a change generated by the community that benefits from it) or endogenous (i.e. an innovation external in origin, but modified and changed by the community that benefits from it).

What this suggests is that LWP cannot easily be predicted by studying the individual behaviour of agents or the efficacy of some single innovation; and that long-term prediction of how LWP emerges will be subject to considerable uncertainty. It also suggests local levels of livestock–water productivity will be patterned rather than random, and that these patterns will have arisen out of the interactions of local sets of agents, strategies and artefacts in response to their environments. It is our contention that as innovation occurs, emergent behaviours arise, and these represent changes to social institutions, as discussed below.

Designing innovation systems for achieving adoption and dissemination of technological and institutional innovations could help researchers and other development actors to develop strategies to promote improved crop–livestock production systems, to define changes as it occurs, to describe the links between system components and to identify indicators to measure both processes and impact of innovations (Springer-Heinze *et al*. 2003).

Noble *et al*. (2008) argue that the key drivers in the development of so-called 'bright spots' (i.e. successful examples of the reversal of land degradation) are as follows:

(1) Individually-based drivers (so-called human capital assets), comprising leadership and aspirations for change.
(2) Community-based drivers, which comprise the relations that enhance cooperation; these include social institutions, reciprocity and exchanges, social capital and participation.
(3) Technically-based drivers, including innovation and appropriate technologies, quick and tangible benefits and a low risk of failure.

Figure 1 presents a conceptual framework for an LWP innovation system, which draws on the above broad drivers. We propose that community and individually-based drivers can be merged into a single driver; and we also propose that a conducive policy environment is an essential driver for innovation success. Hence, this conceptual framework comprises three key components: the policy environment, institutional drivers and technical drivers. These are typically scaled – hence, policy is often broad-scale, institutions at an intermediate scale, and technological innovations 'nested' or 'embedded' within these contexts. The integration of these various innovations is envisaged to positively affect livestock–water productivity and improve farmers' benefits in terms of increased income, food and resilience.

### *Component 1: technical innovations*

The key technological innovations identified for improving water productivity (Peden *et al*. 2007, 2009) are those: (1) that can help farmers to produce sufficient, quality fodder without strongly competing for water with other system components. This is done primarily by adopting technologies and practices which would help to increase productive transpiration at the expense of non-productive evaporation and run-off; (2) adoption of water management interventions that can help farmers to save, store and make economic use of water resources. Here, under-utilised water is diverted to productive uses, storage for dry season use, minimising water contamination, and promoting multiple use of water for various production objectives; (3) since livestock mortality – particularly through disease and feed shortages – is a major challenge faced by sub-Saharan African farmers, high returns can be gained by minimising mortality and morbidity rates through effective and timely treatment of animals and making

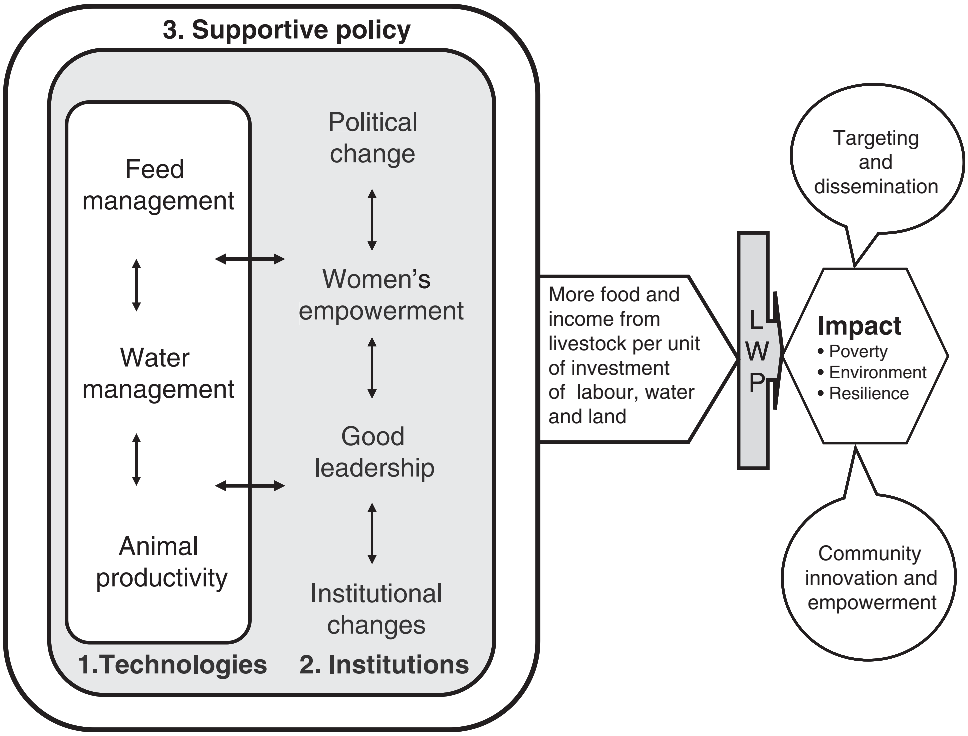


**Fig. 1.** Components of innovation systems to address poverty, environmental degradation and resilience through improved livestock–water productivity interventions.

quality dry season feed available; (4) the way livestock is kept and managed affects LWP. Determining the carrying capacity of the system, improving crop–livestock integration, stall-feeding, and improved feed management including practices that encourage more efficient grazing are key ingredients for improving LWP; and (5) strategic provision of drinking water – providing adequate quality drinking water, strategically placed – enables animals to reach otherwise inaccessible grazing areas, keeps them from contaminating domestic water sources, and enhances production. Given the high value of livestock, particularly to poor households, and the relatively small amount of water animals drink, strategic provision of drinking water is a good investment. These innovations, though technically feasible, however, have commonly failed to be adopted by end-users because they are either beyond the reach of poor livestock keepers or developed without considering the institutional, cultural and economic contexts of target communities and their institutions.

### *Component 2: institutional innovation*

Institutions are '*...the rules of the game in a society or, more formally...the humanly devised constraints that shape human interaction*' (North 1990). Institutions form within the boundaries of complex adaptive systems and therefore define the latter as systems within which behaviour is not random, and from which new behavioural forms emerge. However, institutional framework evolves in response to organisational arrangements including political, social, economic and educational bodies (North 1990). Wilson (1982) argues that institutions will emerge once three conditions are met:

(1) that a dilemma is encountered repeatedly under more or less similar circumstances in which individualistic opportunistic behaviour is seen to destroy the possibilities for collective gain (i.e. it must be seen that the benefits to be gained from acting alone will be less than the benefits to be gained from acting together);
(2) an information network – arising from trading, competition and other interactions – exists which can form the basis for identifying and negotiating possible rules; and
(3) there exists a collective basis for the enforcement of these rules (i.e. the rules must not only be designed in such a way that they can be enforced collectively, but also that there is a collective available to do the enforcing).

In many respects, the above implies that institutions (and hence, innovations) evolve at a pace set by the urgency with which a dilemma needs to be solved. Some thinkers, however, also perceive rapid innovation uptake following a 'critical state' – such as a drought, famine or war), where the very survival of a society is called into question, and hence, innovation flourishes at this point, and rapid and potentially substantial change will occur (Douthwaite 2002). At such a point, the society in effect 'tips over' into a new institutional arrangement, complemented with the innovations needed for this change to succeed (cf. Bak 1996).

As society moves through time (a system), the behaviour of individuals and interactions between agents are modified and limited by institutions (cf. Ostrom 1990). Institutions themselves evolve as conditions change, and can be influenced to alter the way in which livestock, water and land resources are exploited. Indeed, where change calls for altered behaviour, for example, by implementing new management systems – then there is very little difference between the concepts of institutional change and innovation. Where innovation revolves around the introduction and modification of an innovative artefact, such as some technical innovation, then institutional change typically has to accompany the artefact if the latter is to positively benefit a society. Indeed, it is unlikely that technical innovation will occur without corresponding institutional change.

### *Component 3: the policy environment*

Clearly, policies to support or at any rate, not to hamper, positive innovations are essential to their success. Such policies can occur at a variety of scales. While by-laws and local regulations at community level are important for the day-to-day implementation of the designed strategies, district and national policies are instrumental to link the farm with the national policy arena. The FAO (2003) has suggested that agricultural policy in sub-Saharan Africa should encourage small-scale farmers to engage in productive farming by improving the delivery of water resources and expanding economic opportunities by addressing externalities that inhibit the adoption of improved agricultural practices. These policy directions could also facilitate market linkages, technology flows and practices, direct resource distribution and management, and which can influence the uptake of such technologies.

Moreover, the positive effects of these innovations on poverty alleviation and improved livelihoods can be realised if there is a systemic integration of livestock, land and water in space and time responding to the system requirements, market demands and social needs.

These, then, are some of the theoretical underpinnings of innovation systems theory and conceptual framework that informs our interpretation of the case studies that follow.

## Case studies

### *Case study 1: leadership in a mixed livestock–wildlife system in Kenya*

The Il Ngwesi Community consists mainly of Maasai pastoralists living on the Laikipia Plains of north-central Kenya. The community owns and runs a group ranch that covers 165 $km^2$, and contains a population of 500 households. Next to the ranch lies the highly successful Lewa Downs Wildlife Conservancy, an established wildlife sanctuary. Its success has in large measure arisen because of its owner's initiatives, of working up close relationships with conservation-minded donors and NGOs, and of expansive social networks that extend into the Maasai community and far beyond Laikipia. The owner is, in other words, a man with considerably more power than the neighbouring Maasai.

Over the years, livestock grazing pressure and inter-community conflicts over pasture arose in Il Ngwesi. Competition between wildlife and domestic livestock for the available pasture and water was aggravated by frequent droughts and famine. At the same time, Lewa Downs faced a problem. Its elephant populations were growing so large that the Conservancy's area could no longer support them. The Conservancy's owner needed additional land, water and safety for these animals, and it was with this in mind that, in the late 1980s, he began negotiating with his neighbours.

The result was a complete reconfiguration of the Il Ngwesi Group Ranch consisting of two main elements. First, the designation of nearly half the group ranch – 8000 ha – as a conservation area, in which habitation was banned and livestock grazing was permitted only in times of need; and second, the construction of a luxury eco-lodge that generated revenue for biodiversity conservation (patrols that guard against poaching, overgrazing and 'excessive' logging) and for investment in community infrastructure and services (Swallow *et al*. 2007). The implication was that improved grazing management improved soil water infiltration and feed availability, which would in totality improve livestock water productivity at landscape scales (Cook *et al*. 2009).

Moreover, the lodge is managed and staffed by the local community, who act as guides to visitors both at the lodge and on bush walks. Benefits from the Il Ngwesi lodge have been realised on several levels. Revenue currently stands at KShs 3 million per year (*c*. USD 47 000), of which approximately one third is paid out in salaries, a third covers ecotourism operating expenses, and a third is available as benefits to the community in the form of community projects identified by the group ranch committee and approved by members. The highest priority is the provision of schools (so far, three schools have been improved), followed by school bursaries and the provision of health facilities. Funds are also used for road building and providing transport, as well as building cattle dips (Watkin 2003). Management of the Group Ranch lies in the hands of the Il Ngwesi Community, although the owner of the Lewa Downs Conservancy maintains his interest as a member of the board.

This example is illustrative of how instrumental ('good') leadership can be in generating positive resource-conserving outcomes, while at the same time, yielding dividends to the powerless. While the leader, in this case, seems to have avoided confrontation with dominant elites, he has been privy to the opportunities available. He has had knowledge of tourism trends, of what an eco-lodge might constitute, of land and water management and practice and so on. This was all knowledge that the Il Ngwesi community did not have or were unaware of. Such savvy is also important in anticipating and rebutting external political threats to livestock, water and land policies. Il Ngwesi has now become a viable enterprise, certain to attract the attention of local, regional and national interests. In this sense, the leader here seeks to work as a buffer between nefarious external political interests and those of the Il Ngwesi community.

### *Case study 2: improved land and water management in north-western Zimbabwe*

The Wange Community of north-western Zimbabwe typifies most of the problems that plague rural communities in Africa: severely degraded land, water scarcity, ~80 000 people in poverty, rampant AIDS, constantly failing crops, dwindling livestock productivity and rampant poaching of nearby timber and wildlife in state lands (Neely in Noble *et al*. 2008). The Africa Centre was established to reverse this situation, starting its own community. The Centre believes that neither improving water availability, reversing land degradation nor achieving lasting social change can occur through projects of short duration, and hence refers to itself as a 100-year project. The project is based upon achieving the desired reversal of land degradation and all of its many symptoms – droughts, floods, poverty etc. – through empowering people to take charge of their lives and destiny by using an holistic decision-making framework developed by the Zimbabwean founder of the project (Neely in Noble *et al*. 2008).

The overall achievements to date are that the project is an island of calm in the chaos of today's Zimbabwe. There have been over 2000 village members trained through the conservation projects (grazing management, home gardens, women's banks, wildlife management). All the Chiefs of the vast Wange Communal Lands are Trustees and commit significant time and energy to governance of the Africa Centre (Neely in Noble *et al*. 2008). To date, while many people – black and white – have been losing land, four ranches have been added to the community's piece of privately held land to enable the Africa Centre to now form a College of Agriculture, Wildlife and Conservation Management. The total land now managed by the Africa Centre amounts to just over 8000 ha. The land is held by the Trustees for the good of the community, and has dramatically improved ground cover, forage for livestock and wildlife, increased water in boreholes and with one of its main rivers close to once more becoming perennial in flow. Wildlife has increased 10-fold or more on the project land (Neely in Noble *et al*. 2008).

Substantial training and coaching has been provided to the community on permaculture techniques and on planned livestock grazing (to reverse land degradation and restore water to rivers and boreholes). This has saved substantial numbers of livestock from death during recent drought seasons. Where the project land had previously been seriously deteriorating and was considered 'overstocked' with 100 head of cattle, the Africa Centre currently runs a herd of over 600 cattle, goats, pigs, donkeys and horses with dramatic benefit to the land. Improved land, water and livestock management are key strategies to improve livestock–water productivity (Peden *et al*. 2009).

### *Case study 3: ducking interference: an example of water management in a mixed crop–livestock system in Tanzania*

Farming on Tanzania's Mt. Kilimanjaro has been dominated by the Chagga people for between 300–450 years. On the upper slops of the mountain, they practice a tenurial system called '*kihamba*', based on private property rights. *Kihamba* was, and still is, farmed with remarkable intensity. Even in the 1940s, there was very little *kihamba* land left that could be used as pasture, and most livestock was stall-fed (Johnston 1946). Against this background of high farming intensity, the Chagga devised furrow systems to deliver water from natural watercourses to their crops and livestock feed. This system is said to be one of the oldest (thought to have started in the 18th century (Gillingham 1999)) and most extensive furrow-based irrigation systems in Africa (Røhr *et al*. undated). Today, there are some 500 furrows on the mountain, 1800 km of main channels, which, together, abstract some 200 million $m^3$ a year (Gillingham 1999). These systems are inefficient, losing between 15 and 20% of the water that passes through them (Mwamfupe 2001), partly because of poor integration of livestock into their irrigation schemes.

Despite the apparent farming intensity and population pressure on *kihamba* land, traditional institutions of governance and conflict prevention appear to have been effective. Johnston (1946) commented that '. . .it is remarkable that, with a big and complicated furrow system in the kihamba land, so well are matters run by the furrow elders, that the number of cases arising out of disputes over water rights are relatively few' (p. 4).

The Nshara Furrow is a single irrigation canal located in the Hai District on the mountain. It draws between 40 and 60 L of water a second from the Makoa River, depending on the volume in the river. Water from the furrow is used for agricultural and domestic purposes. Livestock keeping continues to be common, and typically stall fed on feed crops grown on the Nshara Furrow's water; or else brought in from outside – the fodder trade is common on the mountain's slopes (Mwamfupe 2001).

The furrow is 'formally' administered by the furrow chairman, who is usually drawn from the lineage of the person who originally constructed the furrow. Besides convening meetings to discuss water allocations, the chairman is also responsible for organising work gangs to clean the channel annually. By contributing labour to these work gangs, individuals gain the right to draw water from the furrow. Once a user has drawn water, the same person cannot do so again until all other users have also drawn their share, at which point the cycle repeats itself.

This administrative system is accompanied by a series of rules and enforced by local institutions is necessary. Users who fail to contribute to the furrow clean-out are punished. Most punishment in this system relates to people failing to contribute towards furrow maintenance.

The rules are also gendered. Both men and women can irrigate, but it is usually the man's responsibility to apply for water allocations, and to irrigate banana and coffee plants, while women irrigate vegetables. It is considered taboo for women to maintain the furrow. Female-headed households are excluded from furrow work, unless she can send a male household member or to pay for someone to do the work in her stead.

The corollaries to these formal rules are what Gillingham (1999) refers to as 'working rules'. Peoples' circumstances along the furrow vary and influence the amount of water that they need. For some, if their plots are very small, they do not need a full 12-h allocation. There are those who cultivate crops only for subsistence needs, and need less water than those who sell some of their crop and who need to irrigate for more than 12 h. On the other hand, every household is allowed to water their livestock throughout the year regardless of the herd size. As such, working rules relate to those rules that represent the manipulation of the formal rules to meet social, cultural and political variations among the furrow's irrigators. Those who need amounts of water greater than their allocation employ five different ways of securing these. The first is to 'borrow' water from someone they know who needs less. The second is to obtain additional water from some other furrow. The third is to buy water from someone offering to sell part of their allocation. The fourth is to irrigate at night when there are no water allocations. Finally, the fifth way is to steal it by, for example, irrigating while it is someone else's allocation day. The flexibility of these working rules, Gillingham (1999) argues, '. . .is crucial to the allocative efficiency and sustainability of the irrigation system. . .If all furrow users were restricted to the use of their formal allocation only, the furrow irrigation system would meet the irrigation water needs of only a few furrow users'. Gillingham argues that the system is reliable, because stealing is permitted neither under the formal allocation system nor under the working rules – if the system were unreliable, people would not contribute to the furrow's maintenance. Such a dynamic political system takes time to develop – the first furrows were dug on Mount Kilimanjaro in the 18th century. In lowland areas, where settlement is more recent, the climate drier, the population more scattered and social diversity much higher, cohesion between formal and working rules is not so great. The key ingredient in the success of this system, Gillingham argues, is the lack of external interference; it is only in the absence of such interference that the system has been able to evolve, the formal power structure maintained, and working rules developed.

## Introducing change

The above case studies are strong samples from among many successful land and water use initiatives across Africa (cf. Reij and Waters-Bayer 2001). In addition, 'bright spots' research work (Bossio and Geheb 2008) provides us with useful pointers as to what drives positive land use change and innovation. It has not been our intention in this paper to eclipse this latter work, but to emphasise key components of change at very local levels. Based on the case studies summarised above, we see institutions as being essential to this process, but embedded within these are political systems, gender and leadership.

### *Institutions*

Institutions are an essential entry point for innovation. Case study 3, described above, elaborates the ways in which 'formal' rules of use need complementary 'informal' rules to smooth out inequalities and other political tensions. It should be noted that rules in social institutions are not 'iron cast', and are constantly debated and tested (cf. Ostrom 1990; Ostrom *et al.* 1994); and similarly, that institutions must not be rigid, but fluid, meandering and fluctuating through time and space as conditions change, actors assert themselves and new opportunities emerge (cf. Cleaver 2000). By identifying formal and informal institutions and the kind of pressures and variables that might alter a community's institutional character, the likelihood that an innovation may be taken up is improved (Fig. 1) because:

(1) an understanding is developed as to whether or not an innovation will be considered 'acceptable' to a community – innovations that fall outside a community's institutional limits will not be taken up;
(2) the drivers that may cause an institution to change, including the political relationships that cause undesirable institutions to be maintained (such as subordinate women's roles), can contribute towards the development of system-wide changes over time;
(3) who might respond better, by virtue of personal circumstances and characteristics, to a novel idea can be identified and prioritised in any transfer of innovations;
(4) institutional groups – such as self-help groups, rotating credit groups, funeral groups etc. – who might respond well to an innovation may be identified, and can therefore be targeted.

Institutional factors are relevant to all of the success stories mentioned above, and are indicated in most natural resources management success stories from around the world (cf. McCay and Acheson 1987; Berkes 1989; Allan *et al*. 2003; Bossio and Geheb 2008). Because innovation is a social process, it is not possible to gain LWP improvements unless close attention is paid to institutions and their associated processes in target communities.

### *Political relationships*

Communities are not '. . .bounded, homogenous entities, but socially differentiated and diverse. Gender, caste, wealth, age, origins, and other aspects of social identity divide cross-cut so-called 'community' boundaries. Rather than shared beliefs and interests, diverse and often conflicting values and resource priorities pervade social life and may be struggled and 'bargained over' (Leach *et al*. 1997). Understanding lines of oppression in a society can help to reveal why it is that some people in communities are as vulnerable as they are. Power is relational, in the sense that if one person grows more powerful, it is at the expense of other peoples' power. Hence, if women are to become powerful, it must be at the expense of male power. Men are likely to resist such empowerment, and it is important to identify 'paths of least resistance' that will allow women's empowerment without overly angering men. Politics underpin all natural resource management success stories (cf. Geheb and Mapedza 2008), because they define the strategic positions of individuals and the groups with which they associate. Politics, in other words, defines which relationships are forged and how these will be played out. Good examples are the success of gifted leaders in persuading a community to follow them, how 'working rules' on the slopes of Kilimanjaro are played out, and indeed, the ways in which institutions are debated and ultimately articulated.

### *Gender*

Ultimately, a LWP focus is also about improving the livelihoods of poor people. Approaching LWP from a gender perspective is important for two key reasons. The first is that women in many African societies occupy precarious social, economic and political positions. Every effort should therefore be made to ensure that LWP improvements do not undermine these positions. If, for example, LWP implies that cattle should be stall-fed, and herding was previously a male responsibility, such changes could result in increased workloads for women who suddenly have to collect fodder for the animals in their charge (van Hoeve and van Koppen 2006).

The second reason for a gendered focus is because experience from other sectors suggests that such a focus may yield far greater benefits than a focus on men. In Burkina Faso, men have greater access to fertiliser and to household and non-household labour for their farm plots. Reallocating these resources to women could increase household agricultural output by 10–20% (Alderman *et al*. 2003). In Kenya, if female farmers had the same levels of education, experience, and farm inputs as their male counterparts, their maize, bean, and cowpea yields would increase by 22% (Alderman *et al*. 2003), thereby improving water productivity at the farm level.

Because African divisions of labour are often gender-based, and see women as the primary caregivers to children, their role in livelihoods improvement and maintenance is pivotal. It is our contention that when it comes to LWP improvement initiatives, a focus on women will yield disproportionately greater overall system-wide benefits than a focus on men alone. While this idea is well supported in the literature (cf. Creighton and Omari 1995; Quisumbing 2003), it is not necessarily easy to apply in practice. Gendered roles in African societies are typically deeply institutionalised, and may severely curb a woman's right to access resource bases. 'Community norms regarding the appropriate status for women may even be the greatest barriers to women's control over resources, especially independent rights to the resource' (Meinzen-Dick *et al*. 1997).

### *Leadership*

The role of leadership in the adoption of innovations is not well understood and rarely considered in the innovations literature (although see Pretty 2008). Case studies 1 and 2 suggest that a key leadership quality is a willingness to shoulder the greater part of the political and risk burden associated with an innovation. Given how vulnerable and risk-laden many sub-Saharan African farming systems are, this is a substantial quality. A leader must inspire the people in ways that diminish the appearance of risk, and emphasises the benefits of undertaking that risk. Hence, a leader inspires trust. Furthermore, both of these case studies emphasised enduring leadership as a key quality – successful, system-wide change takes time to accomplish, and leadership needs to be in place to guide and inspire a community for the duration.

Understanding who are a community's leaders (for there may be several) is an essential prerequisite to developing and/or introducing novel ideas and innovations into a developing country community. The leaders may also be essential to the development of indigenous innovation, as well as for studying and modifying externally-sourced innovations. Given that LWP innovations suggest system-wide changes (Fig. 1), obtaining the support and recognition of the concept by community leaders is essential.

## Conclusions

In this paper, we have argued that societies are 'Complex Adaptive Systems' (CAS) from which innovation, such as LWP, might emerge. Complex adaptive systems are contained within institutional limits, which serve to limit individual behaviour for communal benefit. Understanding how institutions work, and which institutions occur in target communities, are important precursors for innovation and change. We argue that social institutions are embedded within wider trends and processes, such as a conducive policy environment, which can play a critical role in whether or not a community is innovative, or which may create the conditions needed for an innovation to be adopted. At the same time, but at lower scales, we argue, political systems operate; indeed, the tensions between human self-interest and the common good may very well determine how it is that CASs work, and explain why innovative behaviour emerges from them. We suggest that political systems are nested within a wider institutional framework, as are gender relations and leadership. Hence, we call for research that explores institutions, political systems, gender relations and leadership as a prerequisite to understanding in what ways, if at all, these mixed crop–livestock systems should be changed.

## Acknowledgements

We gratefully acknowledge the constructive comments of Drs Shirley Tarawali, Don Peden and two anonymous reviewers. The project is supported by Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ), Germany.

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Manuscript received 15 January 2009; accepted 23 March 2009