Chapter 15

Animal Agriculture and Watershed Management: Reconciling Public and Private Good

Ralph von Kaufmann[1] and
Mohamed A. Mohamed Saleem[2]
[1]International Livestock Research Institute, Kenya
[2]International Livestock Research Institute, Ethiopia

Introduction

Approximately 10% of the world's population, 600 million people, live in highland and mountainous regions (Messerli and Ives 1997). They are the managers of the forests and watersheds that are the source of much of the world's water, biological diversity, minerals, timber, and fuelwood. Their actions have far-reaching consequences. The felling of mountain forests can, for example, make remote downstream countries more prone to flooding. It also increases the amount of carbon in the atmosphere. Thus the welfare of mountain people and the sustainability of their food production systems should concern people everywhere, but this is not well recognised. As a result, highland people are marginalised and mountain areas are depleted and the whole world is being impoverished and made less safe.

Belatedly, there is growing awareness amongst enlightened agencies of the consequences to the global environment of neglecting the problems of mountain agriculture (UNCED 1992). UNCED Agenda 21, Chapter 13, and the follow-up regional and global activities, have culminated in the UN General Assembly declaring 2002 'The International Year of the Mountains' with activities planned to highlight the urgency for remedial action. The general stresses and problems that have to be addressed in establishing sustainable mountain agriculture include:

- rapid population growth;
- farming on slopes and the associated erosion;
- remoteness and poor infrastructure resulting in poor access to markets and services;

- limited job opportunities; and
- political isolation and non-participatory development planning.

This paper argues that something not only should but can and must be done to make research more relevant to individual mountain smallholders for the good of all. This will have to be carried out holistically at the watershed scale with livestock as a principle component. This report borrows heavily from collaborative research in Ethiopia (involving the Ethiopian Agricultural Research Organisation (EARO), ICRISAT, ILRI and other colleagues) that seeks to determine the conflicting (positive and negative) attributes of livestock in highland agriculture and thus develop technologies and policy options to ameliorate the negative and accentuate the positive social and environmental effects.

The smallholder's perspective

Mountains are typically densely populated by smallholders whose landholdings are made up of small fragmented pieces of land spread across narrow biomes and also segregated topographically (Rhoades 1997). Even though the landholdings are not physically contiguous, the smallholders regard them as single farming entities because they depend on being able to access resources from the different biomes to meet their needs sustainably. Growing populations force further subdivision of already small plots thereby forcing the adoption of more continuous cropping and impeding the traditional soil and water husbandry practices (Mohamed Saleem 1998).

These circumstances, occurring in Nepal for example, have led to a litany of problems that aggravate each other. Resource-poor farmers are forced to cultivate increasingly steep slopes, seek fuelwood and forage from forest areas, and move their grazing livestock seasonally to very high altitudes (Rhoades 1997). This leads to overgrazing of hill pasture, which impedes regeneration and results in a progressive decline in livestock productivity. The intensified use of marginal lands has accelerated erosion and reduced soil water-holding capacity causing falling crop yields with bleak prospects for the mountain farmers. The same can be said about most mountain systems of the developing world – in Asia, Africa, and the Andes.

Private and public consequences of neglecting mountain agriculture

In densely populated mountains, the problems inherent in situations with unstable soils, high intensity rains, and torrential river flows are exacerbated resulting in damage to hill irrigation structures, silting up of reservoirs and irrigation canals, and degeneration of riverbeds in the hills and lowlands. This causes floods and loss of agricultural production in the lowlands as a result of siltation. Wells in the hills dry up in the dry season, forcing people to spend more time collecting water or to migrate to the lowlands. This situation illustrates the connection between the private good of the mountain farmer and the public good of the wider public, which depends on mountain resources.

The population-induced stresses on smallholder mountain farming systems are being aggravated by the consequences of climate change in more severe and threatening ways than is evident in lowland agriculture. Areas above 4,000 masl have, in the past, been protected from cultivation by the cooler mountain temperatures, which set limits to cropping in the upper reaches. Seasonal gathering of tree products and livestock grazing were the main land uses at these altitudes. However, it is predicted that global warming will force large areas of tropical lowlands out of production, while at the same time making the very high altitudes thermally suitable for agricultural use. This will move farming systems into higher altitudes where low temperatures have limited weathering and, therefore, the soil depth thus increasing the risk of land degradation. Furthermore, melting snow caps and changes in the hydrological cycles will increase the incidence of damaging flash floods and droughts.

The effects of warmer climate over the past ten years in the Ethiopian highlands are indicated by incidences of malaria in places above 1,800m. This is threatening people who have no acquired immunity. Similar changes in the epidemiology of livestock diseases are also attributed to increases in temperature.

Such changes demand the development of new sustainable land-use systems for the mountains that will provide for the local inhabitants yet protect the interests of lowland people. These will not develop spontaneously because of the conflict between the immediate demands of smallholders and good environmental practice. Research is required to find answers to this conundrum.

Research needs

In the past, research and development strategies developed in the lowlands were extended to the mountains without due consideration of the different requirements of vertical and fragmented terrain. This was not successful; new farming systems need to be developed to suit the interlinked requirements and functions of small plots of land of varying quality distributed in different locations and altitudes, especially with respect to soil and water management.

It will only be possible to improve the welfare of smallholders if land-use systems are developed that meet their needs for cropping and for access to woodland and grazing resources while at the same time protecting wider interests in soil and water management. Proper management of mountain watersheds is dependent on reconciling individual and collective demands and responsibilities in managing natural resources. Crop cultivation and animal agriculture are vital integrated components of sustainable mountain-watershed management.

Livestock, with their capacity to cause degradation through overgrazing and demand for forage, can be extremely damaging to steep slopes. On the other hand, livestock can be very valuable in supporting the sustainable use of land resources if their ability to utilise grasses, browse, and crop residues, and to supply manure and farm power is wisely integrated into the farming system. They also generate revenue and form capital assets that enable smallholders to withstand the pressures put on them to practice unsustainable cropping and woodcutting for their day-to-day survival.

The role of livestock in production systems

Livestock have many functions, but producing food, or the money to buy food, are the most important (Mohamed Saleem 1998). Foods from animal sources provide calories, high quality bio-available protein, and micronutrients such as vitamin B_{12} that are not available in plant foods and which are critical to human health and especially childhood development. Food supplements from animal sources also enable humans to extract more micronutrients from cereals.

Studies in Mexico, Kenya, and Egypt have shown that children with access to foods from animal sources had better health, growth, and cognitive development than their counterparts who were restricted to diets wholly from plant sources (Neumann 1998). This is of critical importance because it is the key to enabling children to achieve their full individual and collective potential to contribute to national development.

Livestock also make important contributions to cropping systems through the role of manure and urine in soil nutrient cycling. Animal power is in many areas critical to smallholders for tillage and transportation. Animals also provide social and financial security for smallholders who have few alternatives for building assets that can sustain them through droughts and other calamities. However, although livestock are individual property, they typically draw on common land and water resources in different parts of the landscape at different times of the year, and they can cause adverse effects by grazing, trampling, harvesting of forage, and the disposition of animal wastes that impinge on all the people that share the resources, regardless of their personal livestock holdings.

Reconciling private and public goods

In earlier times, agricultural research focused on improving animal and crop productivity independently of each other. However, in the seventies and eighties it was recognised that crops and livestock interact and must be considered jointly when optimising whole-farm performance. More recently it was recognised that research had to go well beyond farm boundaries to ensure positive impacts on poverty alleviation, natural resource management, and protecting the environment. This recognises that activities on private farms have to be reconciled with societal aspirations, especially with regard to watershed management.

Watersheds are segregated by steepness of slope and soil type because different combinations of these characteristics create different production potentials and limits and require different technologies for sustainable use. The farmers are aware of this, but land pressures and the lack of alternative technologies and policy disincentives for change have led to unsustainable land use. How to help highland smallholder farmers find new solutions to these problems is the main focus of the participatory research by a consortium of institutions working in Ethiopia, involving EARO, ICRISAT, and ILRI. The results of a pilot project in the Ginchi watershed are described here as an example.

Livestock as a Means of Improving Watershed Management: the Ginchi Case Study

The situation

A 350 ha sub-watershed was demarcated for detailed study of the problems and potentials for sustainable land use within the larger Ginchi watershed that drains into the Awash River which flows eastward down the Ethiopian highlands. The changes in this watershed are representative of the major general trends observed in highlands with increasing population pressures (Figure 15.1). In the 1950s, 70% of this watershed was grazed pastureland and there were no more than 9,000 metres of drainage channels. Over time, the number of people and livestock depending on the watershed has increased and most of the pastureland, even on steeper slopes, has been converted into cropland, which today covers 70% of the area. The soil has been eroded, new gullies have formed, and the old ones have widened and deepened to a total length of over 18,000m (Alemayehu Mamo and Mohamed Saleem, unpublished). The watershed no longer provides sufficient food for the resident families, nor sufficient grass for livestock feed and thatching, especially in the dry and early wet seasons.

The smallholders depend on oxen for tilling the soil and threshing crops. Cows provide milk for home consumption and for sale to generate a daily income. Cattle and sheep provide meat for domestic use and sale. Horses and donkeys are kept for transport. After the crops are harvested, these livestock are free to move anywhere in the watershed. During the crop-growing season, however, they are confined to the steeper slopes and banks of the watercourses – and the stocking rate on the common lands is very high. The biomass available is neither sufficient to feed the animals nor

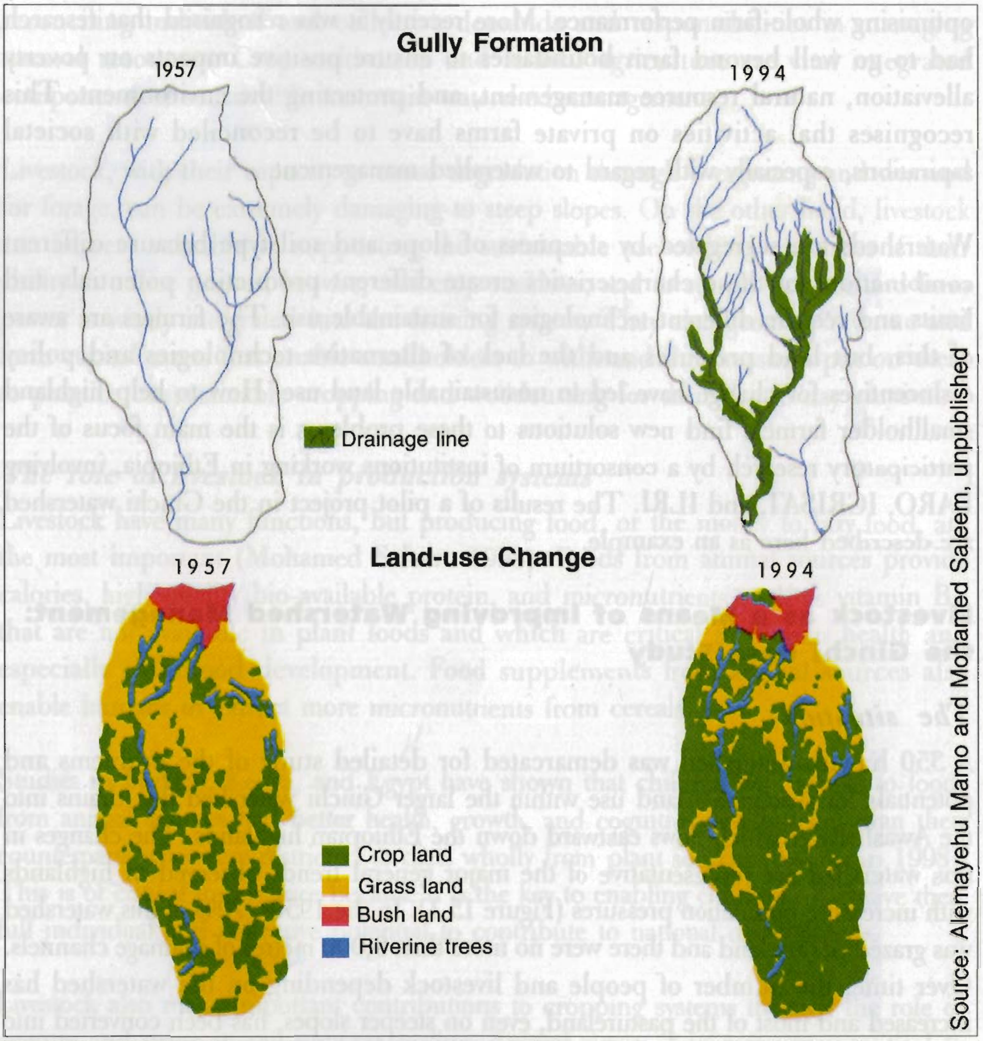

Fig 15.1: **Digital land use map of Ginchi watershed**

to provide an effective cover to protect against erosion or impede water flow down the slopes (Mwendera et al. 1997a). Until crops are planted, ploughed slopes without vegetative cover rapidly lose their shallow soils. The Ethiopian highland area is estimated to lose over 2 billion tonnes of soil annually (EFAP 1992).

Water stagnates in the high clay content Vertisols (black cotton soils) of the shallow valleys making cultivation difficult, and crops are not sown on these soils until the latter part of the season when the surface water has receded. Improving the drainage is complicated by the fact that separate pieces of small landholdings of individual households are scattered across different parts of the watershed. These pieces have to be spatially and socially integrated with the landscape and the community needs.

Table 15.1: **Framework for animal agricultural research in the Ginchi watershed**

Problem	Reason	Consequence	Solutions	Constraint
Prime lands Productivity in the prime lands is low. There is a need to maximise production of food for people as well as feed for livestock from the same land unit.	- Declining soil fertility and little or no application of fertiliser. Dung used as fuel and not recycled back to the fields	- Opening up of more land from grazing areas to grow food crops	- Apply appropriate level of fertiliser to replenish and maintain nutrients - Recycle dung - Introduction of forage types that fix N biologically into the farming system	- A costly operation for the average farmer, recommended levels cannot be used - Dung is needed for fuel and there are not many alternative fuel sources - There is no technology to integrate forage in the farming systems
	Actors: The solutions require individual actions, but the benefits of maintaining soil nutrient status will impact others using the watershed.			
	- Some of the prime agricultural lands not fully utilised because of waterlogging (e.g., the Vertisols' area) for part of the year	- Only part of the growing season can be used and there are only limited types of land use	- Develop beds and furrows to improve drainage and suitable cropping packages for the changing opportunities	- Traditional animal drawn implements inadequate for shaping land, manual land shaping very laborious and involves women and children - Draining water from a farmer's plot accentuates the waterlogging problems of the neighbouring farmer below
	Actors: Individual decisions to improve drainage and intensify land use will have to be supported by the community, collective action is required to produce a common drainage system (public good) which will also maximise the benefits of individual farmers (private good)			
Livestock population far exceeds the carrying capacity of the watershed	Different livestock are kept for different purposes (e.g., oxen for draught power, cows for milk).	More livestock per unit area, particularly under demographic pressure to increase crop area; therefore feed shortage and land degradation	Use of the same animal for different purposes (e.g., using cows as draught animals).	Social prejudice against using cows for draught as they are considered too weak to perform 'hard work' such as pulling a plough
	Actors: Individual decisions can be encouraged by collective support			

Table 15.1: Framework for animal agricultural research in the Ginchi watershed (Cont'd)

Problem	Reason	Consequence	Solutions	Constraint
Common land Low animal productivity due to feed deficiency, grazing animals without supplementary feed suffer most	- Animals are spatially confined to common river-banks, rugged terrain, and steep slopes that are marginal for cropping, particularly during the wet season. - Although animals have open access to any part of the watershed after the crop harvest, the feed available during the dry season is inadequate in quality and quantity.	Overstocking and grazing, inadequate regrowth of vegetation accentuated by soil erosion and nutrient deficiency (made worse when dung is collected for fuel), lower water infiltration and compaction	- Reduce the number of animals - Release more common land for grazing by intensifying land-use and increasing productivity of grain and fodder in other parts of the watershed (more gently sloping areas)	- Different livestock have separate functions and therefore all animals are needed. Suggestion of reducing animal numbers not welcomed by farmers, and they have no incentive to do it - Lack of alternative technologies for intensification of land-use
	Actors: Although the ultimate benefit from both solutions is of a public nature, solution 1 requires collective action, while solution 2 requires action to intensify production by individual farmers for collective benefit from freeing up grazing lands.			

A general framework of the situation was developed to determine what animal and agricultural research would be required to generate appropriate technologies and to assess their potential private and public impact at the watershed level. This framework – the research model – is shown in Table 15.1.

Intensifying land use

The size of landholdings and number of livestock kept are shown in Table 15.2. Typical of the region, the Ginchi farmers are poor, with family landholdings ranging from 0.25 to 4.75 ha. Each family has on average 1.34 draught oxen and 0.86 cows. The more fortunate families that own more oxen also have larger landholdings and cultivate more land. The principal grain crop is teff (*Eragrostis tef*), which is grown on the Vertisols found in the lower shallow valleys (slope 0-4%) of the watershed.

Although the rainy season starts in May, teff is not sown until late in August or early September because the Vertisols are waterlogged. This leaves the soil exposed for two or three months after being ploughed at the onset of the rains.

A commitment to long-term research was required to develop ways of draining the Vertisols that would allow earlier planting to diversify cropping and provide better soil protection. This was ultimately achieved by modifying the traditional oxen-drawn plough 'maresha' by joining two of them together with a 1.2m space bar and attaching wings to the inner sides of the ploughs that lift the soil into beds separated by drainage furrows. With constant consultation with and participation of the farmers, the 2,000 year-old 'maresha' was adapted into a broad bed maker (BBM) that can be drawn by the traditional pair of oxen (Figure 15.2). The farmers can now sow cereals as early as June and the long growing period to January/February opens up opportunities for multiple cropping in sequences or relays and in mixtures of

Table 15.2: Mean landholding, number of plots, and number of livestock kept in the Ginchi watershed area

	Mean holding per household	Range
1. Landholding (ha)	3.35	0.25-4.75
2. Plots (no.)	6	1-14
3. Livestock holding		
Draught oxen	1.34	0-4
Cows	0.86	0-3
Heifers	0.47	0-3
Young bulls	0.40	0-2
Calves	0.67	0-4
Goats	0.47	0-11
Sheep	0.70	0-6
Donkeys	0.49	0-3

Source: Ginchi watershed survey data 1996 (unpublished)

Figure 15.2: Ethiopian traditional 'maresha' plough (a) and latest version of the BBM (b)

food and forage crops (Table 15.3); at the same time the early establishment of plant cover reduces soil erosion.

The research was carried out on-station and on-farm, but always with farmer participation which included:

- designing implements and testing the animal power required to pull them through soils of different consistencies;
- testing the arrangements of broad beds on slopes of varying steepness to minimise erosion and determine the slope-limits of the technology;
- screening suitable types of crops and forage and developing strategies for attaining compatible associations;
- developing strategies for optimising food and feed quantity and quality per land unit; and

Table 15.3: **Grain and fodder yields from different use intensities of Vertisols**

Land-use types (LUTs)	Mean yield kg dry matter per year				Total fodder kg dry matter per year
	Grain	Crop residues	Sown forage	Weeds	
Only local wheat	0.70b	1.54d		0.52 bcd	2.1 d
Only improved wheat	1.57a	4.06b		0.38 cde	4.4 d
Only lablab forage			13.34 a	0.34 de	13.7 a
Only sesbania			0.73 c	0.95 a	8.2 c
Sesbania-lablab mixture			10.86 ab	0.57 bcd	11.4 ab
Improved wheat/clover mixture between sesbania alleys	0.87b	2.46c	3.13 cd	0.74 b	8.8 c
Improved wheat followed by grass pea between sesbania alleys	1.76a	4.85a	4.06 d	0.61 bc	10.2 bc

Source: Mohamed Saleem and Abiye Astatke 1996

[1]Total fodder = crop residues + sown herbaceous and tree forage + weeds as appropriate to LUTs

Means followed by the same letter within a column are not significantly different ($P<0.05$)

- developing strategies to optimise the use of the extra feed produced by the improved land-use systems.

Use of the BBM has significantly and sustainably increased food and fodder production for those who have adopted the system. Protection against soil erosion not only makes the private cropping systems more sustainable but also reduces sedimentation of communal watercourses. At the same time, improved drainage from the upstream lands can lead to increased water reaching downstream plots, where it causes increased problems. Thus for the benefits to be realised on a wide scale, communal planning is required to avoid water shed from one farm merely adding to the problems of the downstream neighbours.

Intensifying livestock production

There are fewer livestock diseases prevalent in highland areas than in tropical lowlands. Thus high potential breeds can be introduced from temperate countries even though they are susceptible to tropical diseases. Through a government-promoted scheme, smallholders in Ethiopia have adopted Friesian crossbred cows that produce much more milk than the indigenous breeds. However, these cows require more feed than the local cows, and they have to be supplemented with purchased feed. This absorbs much of the extra income from increased milk sales.

The farmers also have to care for and find year-round grazing for the oxen they need for ploughing, even though the ploughing season only lasts six to eight weeks (Gryseels and Anderson 1983). In the search for more home-produced feed for the more-profitable dairy cows, research was undertaken to determine if the crossbred cows could provide the draught power and replace the oxen. Exploratory on-station research proved that dairy cows can produce milk and provide sufficient draught power without any adverse physiological effects, provided that they are adequately fed (Table 15.4). The farmers who observed the dairy-draught experiments expressed interest in the technology and volunteered to participate in on-farm trials. Replacing ox-power with dairy-draught technology has proven to be feasible so long

Table 15.4: **Milk yield of working and non-working F1 crossbred dairy cows at smallholder farm level**

Work Status	Daily milk yield (kg)	305 days milk yield (kg)	Lactation yield (kg)	Lactation length (days)
Working	5.1	1501	1725	381
Non-working	5.6	1682	2104	426
Lactation				
First lactation	5.8	1740	2071	410
Second lactation	4.9	1443	1758	398

Source: Mengistu Alemayehu et al. 1998

as the farmers have good access to milk markets, animal health care, and breeding services. The quality of the roads and distances from urban markets are major factors in determining the costs of sales and, therefore, the feasibility of the technology.

In a situation where farmers collectively recognise the limits to the stock carrying capacity of the watersheds, the dairy-draught technology represents an attractive mix of private and public good because it enables the reduction of animal numbers and the restriction of animal movements in fragile areas while increasing smallholder incomes. The feed released by the displaced oxen leads to more profitable milk production, and the manure and urine can be more readily collected for use as organic fertiliser. In Nepal, manure is used for generating 'biogas' with the slurry still providing a good fertiliser. This reduces the pressure on wood as a fuel for cooking and heating and has had a significant impact on forest regeneration and protecting tree cover. It might be possible to introduce this type of technology in other areas, for example, the Ginchi watershed, to solve the problems caused by using manure for heating purposes. An unexpected benefit of the dairy-draught technology observed in Ethiopia is that by eliminating the need to herd oxen more children have been able to attend school. However, the benefits of the private and public good from dairy-draught technology cannot be realised unless it is supported by enabling policies that encourage farmers to invest in innovations and use the common land rationally.

Managing Common Resources

In mountain areas in developing countries, livestock have open access to land that is unsuitable for cropping. The livestock belong to individuals, but uncontrolled grazing causes damage that is shared by all,and better practices are required to protect the communal interests.

Terraces and other methods of physically retaining the soil on slopes may be applicable for high-value crops but are generally too expensive. Alternatively, sod forming with creeping forage can provide an effective alternative soil protective cover, depending on the biomass threshold required for soil protection on different slopes (Figure 15.3). But grazing has to be regulated to maintain the threshold levels of biomass (Mwendera et al. 1997b). At moderate grazing pressures, regrowth of pastures is stimulated and deposition of manure helps to keep the botanical composition in a dynamic equilibrium. The threshold grazing intensity and frequency and acceptable nutrient loss and replenishment strategies can be established scientifically. But the grazing regulations have to be enforced by collective agreement and action. There must also be alternative sources of feed to make up the deficiencies when grazing pressures have to be reduced at crucial points in the growing season.

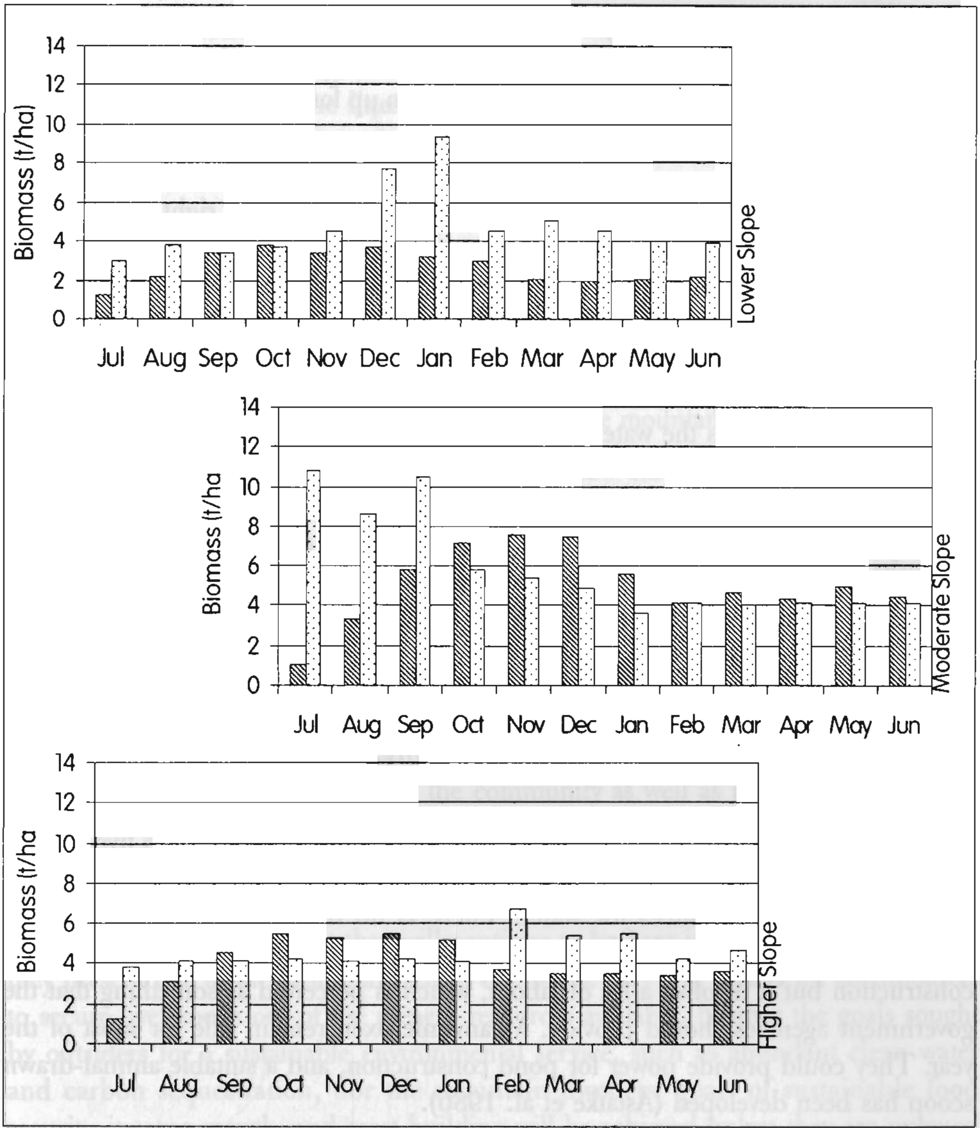

Figure 15.3: **Standing biomass and estimated amount required to support livestock and protect soil on different slopes in the Ginchi watershed**

Almost by definition, people living in watersheds have to be concerned with the movement of water down the watershed. Where there is intensive farming drainage channels are needed that pass between privately-owned fields and through common lands. Without care, as seen at Ginchi, erosion can spread rapidly to damage the channels, taking good land out of production. Ways have to be found to motivate individuals to cooperate with others to design and manage the waterways. This requires finding linkages between public and private interests in watershed management. In the example of the Ginchi watershed, it was shown that by improving drainage using the broad bed maker, farmers can actually create negative consequences downstream. Smallholders with contiguous plots need to lay out their drainage systems jointly and link these to a common drainage channel. This requires some land to be given up for construction of the channel, which gives rise to complex communal problems that require skilful handling.

At Ginchi, research was required to determine how to access the right of way across private lands and how to recruit the labour required to construct the common channel. The landowners and their families had to be persuaded that their investment would be justified by sufficiently increased farm productivity. The planning and negotiations were complicated. It was not possible to form more manageable sub groups of farmers because the landholdings of each family were widely dispersed across the watershed; construction of the channel had to be agreed upon by most residents of the watershed. Ultimately, it was found that leadership in the drainage project conveyed status in the society and this motivated individuals to participate. The participatory process, encouraged by the researchers, facilitated negotiations that proved to be sophisticated and subtle. It was found that the residents did not invest their labour equally. Those who had more land in the watershed and owned plots with at least one border along the channel contributed most labour. In other words, individuals who had the greatest private stake in the collective endeavour contributed more to the construction and success of the public good (Mohammad Jabbar and Mohamed Saleem 1999; Gaspart et al. 1998).

The average annual rainfall in Ginchi exceeds 1,200 mm, but for four to five months of the year women fetching water for their households and children herding livestock have to walk long distances for water. There is no tradition of sinking wells or constructing ponds to conserve water. Extension staff have encouraged pond construction but it involves a lot of labour, which is perceived as something that the government agencies should provide. Meanwhile oxen remain idle for most of the year. They could provide power for pond construction, and a suitable animal-drawn scoop has been developed (Astatke et al. 1986).

Under the former communist regime, farmers, at the instruction of peasant associations, committed oxen and labour to dig ponds in some parts of the Ethiopian highlands. The people for whom the ponds were meant could not opt out of contributing. Nevertheless arrangements were made to accommodate differences in private resources and interests. Animal owners contributed in accordance with the number and condition of their animals. People who did not own work animals were expected to contribute in other forms.

These peasant associations have now been dismantled, but people with access to the ponds are grateful to the associations even though it was they themselves who constructed the ponds. However, despite the appreciated benefits of reliable sources of drinking water in the neighbourhood, there are no ponds in the Ginchi area and research is needed along the lines of that undertaken for constructing the common drainage channel to find a means of motivating and organising the voluntary individual inputs required for the common good.

Conclusions

The scientific community has produced many technologies that are irrelevant to the most urgent needs of smallholders. While this is less prevalent with participatory research, there is still more to be done to make research appropriate to watershed-scale circumstances. This is needed urgently because mountains have not been at the forefront of development policies and the effects of changes in mountain systems are less well understood than in other systems.

The conventional systems' approach to research for development focuses primarily on policy interventions and technology components and their interactions at the household level. To have an impact on human welfare in mountain systems in terms of poverty alleviation, food security, better nutrition and human health, and environmental heath, it is necessary to go beyond household profitability, resource productivity, and resource requirements. Technologies and policies, and their interaction, have to be integrated at the community as well as the household level.

Unless common and private interests are reconciled the conflict between them will be detrimental to both. Livestock are perceived by many outsiders to be bad for mountain environments. But they will continue to be kept in the mountains because they present one of the best, and indeed one of the very few, means for smallholders to secure livelihoods out of the meagre resources available. Neither the goals sought by outsiders for a sustainable environmental service, such as abundant clean water and carbon sequestration, nor the mountain dwellers' goals of sustainable food security, income growth, and asset building will be achieved unless they are pursued through common reinforcing objectives.

Bibliography (not necessarily cited in the text)

Abiye Astatke; Bunning, S.; Anderson, F. (1986) *Building Ponds with Animal Power in the Ethiopian Highlands,* a Manual. Addis Ababa: ILCA

Bos, E.; Vu, M.T.; Massiah, E; Bulatao, R.A. (1994) *World Population Projections 1994-95,* prepared by the International Bank for Reconstruction and Development (IBRD)/The World Bank, p. 521. Baltimore (USA): John Hopkins University Press

Conway, G. (1997) *The Doubly Green Revolution: Food for All in the 21st Century.* London: Penguin Books

EFAP (1992) *Soil Water Conservation,* Working Paper No. 15. Addis Ababa (Ethiopia): Ethiopian Forestry Action Progress

Gaspart, F.; Mohammad Jabbar, M.A.; Melard, C.; Platteau, J-P. (1998) 'Participation in the Construction of a Local Public Good with Indivisibilities: An Application to Watershed Development in Ethiopia'. In *Journal of African Economies* (Oxford), 7(2): 157-184

Gryseels, G.; Anderson, F.M. (1983) *Research On-farm and Livestock Productivity in the Central Ethiopian Highlands: Initial Results, 1977-1980,* ILCA Research Report No. 4. Addis Ababa (Ethiopia): ILCA

Mengistu Alemayehu; Alemu GebreWold; Azage Tegegne; Zerbini, E.; Larsen, C. (1998) 'Dairy-draft On-farm Performance of Crossbred Cows in Holleta Area'. In *Proceedings of the 6th Conference of the Ethiopian Society of Animal Science (ESAP), 14-15 May 1998,* pp 232-240. Addis Ababa (Ethiopia): ESAP

Messerli, B.; Ives, J.D. (eds) (1997) *Mountains of the World: A Global Priority.* London/New York: Parthenon, and Tokyo: United Nations University Press.

Mohamed Saleem, M.A. (1995) 'Fragile East African Highlands: A Development Vision for Smallholder Farmers in the Ethiopian Highlands'. In *Outlook on Agriculture* 24(2): 111-116

Mohamed Saleem, M.A. (1998) 'Nutrient Balance Patterns in the African Livestock Systems' In *Agriculture, Ecosystems and Environment,* 71: 241-254

Mohamed Saleem, M.A.; Abiye Astatke (1996) 'Options to Intensify Cropland Use for Alleviating Smallholder Energy and Protein Deficiencies in East African Highlands'. In *Field Crops Research,* 48: 177-184

Mohammad Jabbar, M.A.; Mohamed Saleem, M.A. (1999) *From Component Technology to Integrated Resource Management: Experience in the Design of a Project Addressing Poverty, Food Security and Natural Resource Management through Farmer Participation.* Paper Presented at IBSRAM International Vertisol Workshop, 8-14 May 1999, Harare, Zimbabwe

Mwendera, E.J.; Mohamed Saleem, M.A.; Dibabe, A., (1997a) 'The Effect of Livestock Grazing on Surface Runoff and Soil Erosion from Sloping Pasture Lands in the Ethiopian Highlands'. In *Australian Journal of Experimental Agriculture,* 37: 421-430

Mwendera, E.J.; Mohamed Saleem, M.A.; Zerihun Woldu (1997b) 'Vegetation Response to Cattle Grazing in the Ethiopian Highlands'. In *Agriculture, Ecosystems and Environment,* 64: 43-51

Mwendera, E.J.; Mohamed Saleem, M.A.; Tadesse, A., (1996) 'Biomass Requirements from Natural Pastures for Livestock Grazing and Soil Protection in the Eastern African Highlands'. In Mwendera, E.J. (ed) *Livestock Grazing*

Impact on Vegetation, Soil, and Hydrology of Pastures in the Tropical Highlands, ILRI Internal Report. ILRI, Addis Ababa

Neumann, C.G. (1998) *Livestock Development and Impact on Women's Health.* Paper presented at an IDRC/ILRI Planning Workshop, May 11-15 1998, Addis Ababa, Ethiopia

Rhoades, R.E. (1997) *Pathways Towards a Sustainable Mountain Agriculture for the 21st Century: The Hindu-Kush-Himalayan Experience.* Kathmandu: ICIMOD

UNCED (1992) *Earth Summit: Agenda 21. The United Nations Programme of Action from Rio.* The final text of agreements negotiated by Governments at the United Nations Conference on Environment and Development (UNCED), 3-14 June 1992, Rio de Janeiro, Brazil