Working Paper

Agroforestry in the drylands of eastern Africa:

a call to action

Bashir Jama and Abdi Zeila

Eastern and Central Africa

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

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Abstract

Drylands in eastern Africa typically suffer from unsustainable land uses that have evolved in the recent past. This paper reports on how agroforestry practices can contribute to sustainable land use in drylands drawing on examples from Ethiopia, Kenya, Tanzania and Uganda, India and the Sahel.

The paper also reviews other drivers of successful dryland rehabilitation programmes and examines opportunities and constraints in dryland agroforestry extension programmes. The paper concludes that agroforestry can contribute to the evolution of sustainable land use in the drylands. This is possible because it is a system that blends production (food and income security at household- and community-level) with ecosystem services. Recommendations for successful implementation of agroforestry extension programmes in these marginal lands are given.

Keywords

Drylands, dryland rehabilitation programme, agroforestry, food security, income security sustainable land use, extension programme, marginal lands, Ethiopia, Kenya, Tanzania, Uganda, India, Sahel, eastern Africa.

Contents

Acronyms and abbreviations

AoCA	Area of Concentration Approach
ASALs	arid and semi-arid lands
CAP	community action plans
CAZRI	Central Arid Zone Research Institute
CP	crude protein
EA	eastern Africa
ICAD	integrated conservation and development
ICRAF	World Agroforestry Centre*
NARS	national agricultural research systems
PMA	the Plan for the Modernization of Agriculture
PRA	participatory rural appraisals

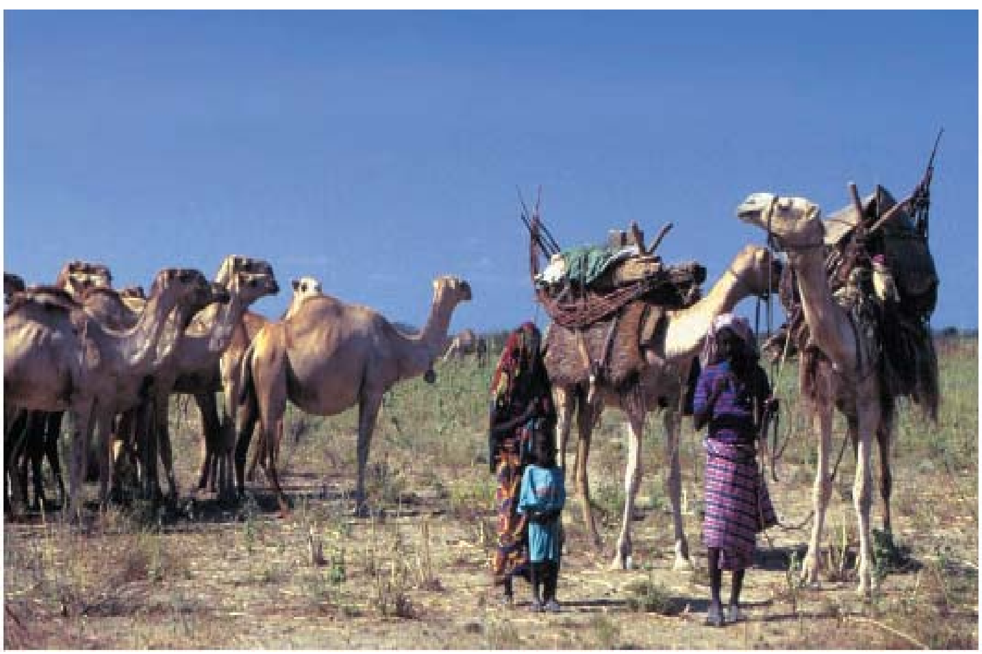
* To more fully reflect our global reach, as well as our more balanced research and development agenda, we adopted a new brand name in 2002 'World Agroforestry Centre'. Our legal name - International Centre for Research in Agroforestry - remains unchanged, and so our acronym as a Future Harvest Centre - ICRAF - likewise remains the same.

Background

Drylands (arid, semiarid and hyper-arid areas in which annual evapotranspiration exceeds rainfall and in which agricultural productivity is limited by poor availability of moisture) occur throughout the world. They comprise not less than 40% of the global surface landmass (6.4 billion ha) and are found in about 100 countries the world over. They are home to about 1.2 billion people and 350 000 plant species, of which 3000 are known to be useful to mankind.

In Africa, drylands cover 1.96 billion ha in 25 countries (65% of continental landmass). More than 30% of the world's drylands are found in Africa. Nearly 400 million Africans live in the arid and semiarid lands of the continent. With the dryland population increasing at the rate of 3% a year, the natural resources of Africa's drylands must feed an additional 12 million people every year; this is despite degradation of the dryland natural resource base.

In eastern and central Africa, the arid and semiarid lands (ASALs) occupy significant landmasses: 75% of Kenya, 50% of Ethiopia and Tanzania, 30% of Uganda and 20% of Rwanda. The total dryland area in Eastern Africa is 5 083 000 km^2 (i.e. 81% of the total surface area); in central Africa, the figure is 216 000 km^2. In addition, the ASAL population is typically impoverished, with well over half of ASAL population living below the poverty line. The prevailing production systems are pure pastoralism, agropastoralism and irrigated agriculture.



A family of pure pastoralists in search of pasture and water. They occupy huge swathes of land in eastern Africa.

Agenda 21, the blueprint for action into the 21st century adopted by world leaders meeting at the 1992 Rio Earth Summit, identifies agroforestry as one way of rehabilitating the degraded drylands of the world. Agroforestry, one of several approaches for improving land use, is also frequently invoked as an answer to shortages of fuelwood, cash income, animal fodder and building materials in sub-Saharan Africa (Rocheleau et al. 1988).

Environmental problems in the drylands of eastern Africa: a diagnosis

The spiral of environmental degradation facing Eastern Africa (EA) drylands is mainly anthropogenic in nature and origin. However, for convenience, the causes of degradation can be classified into demographic failure (phenomenal population growth caused by advances in medical sciences); information failure; market failure (with respect to mainly the livestock economy); institutional failure (very weak/moribund institutional environment); and educational failure.

Land degradation and desertification

Desertification can be defined as land degradation in arid, semiarid and dry sub-humid areas resulting from various factors, including climatic variations and human activities [UN definition]. Land degradation, on the other hand, can be defined as “the aggregate diminution of the productive potential of the land, including its major uses (rainfed, arable, irrigated, rangeland, forest), its farming systems (e.g. small holder subsistence) and its value as economic resource” (Stocking and Murnaghan 2001). However, the two meanings may be used interchangeably.

There are two main culprits in the desertification debate: human factors and climatic influences. Climate variability and climate change has been identified as the natural factors that have contributed to the enhanced pace of desertification in the EA drylands. **Rainfall** is variable in both time and space, leading to droughts and famines. Droughts, which may be defined as persistent below-normal precipitation, lead to mass exodus of people and their herds, forcing pastoralists to migrate to relatively better-watered areas. In the process, overgrazing of the meagre remaining vegetation cover takes place, resulting in even more land degradation. In the areas where the herds are now concentrated, new forms of land degradation take place, especially around watercourses and water bodies such as rivers, boreholes, water pans, etc. **Temperature,** as an element of climate, also contributes to land degradation through its attribute of variability and occasionally by its extreme values. The impact of temperature is exacerbated by the influence of global warming. Drylands are important ‘carbon sinks’, and land degradation and desertification may be contributing to increase in the emissions of greenhouse gases such as carbon dioxide. These emissions are attributable to soil disturbances, fires/burning for range regeneration, land-use changes, biomass degradation e.g. by enhancing soil microbial activities as well as usage of tree resources for meeting energy requirements/needs. Global warming may affect water balance in drylands, reducing moisture availability for plant growth and development. **Wind** is another important culprit of land degradation and desertification. It is a powerful adjunct to human activities, more so when removal of woody and herbaceous cover/biomass has been effected. It is very apparent in areas with loose surface soils or previously eroded soils. The EA drylands are particularly prone to the violent *khamsin* winds, which result in soil erosion on a large scale.

However, land degradation owing to natural factors is usually in tandem with the regenerative capacities of the land. Visible degradation usually occurs when negative human activities become supplemental to the natural factors. This usually results in accelerated pace of land degradation, resulting in desertification at the extreme end. Oftentimes, irreversible land degradation occurs; other times, it can only be reversible through massive infusion/injection of capital and labour. The human activities include overgrazing, over-cultivation, inefficient irrigation systems that do not correspond with soil water requirements and deforestation as well as industrial pollution [on a limited scale]. Other drivers of land degradation are population increases (including enhanced in-migration).

The combined effect of human and climatic factors of land degradation has been a reduction in the production of arid and semiarid lands in addition to the reduction in the quality of the environment due to biophysical loss of resources.

Increasing human population

There has been phenomenal growth in the number of people living in EA drylands. This growth is attributable to both advances in medical sciences as well as significant in-migration into drylands from higher potential land due to over-stretching of the agricultural and land resources in those areas. The increased population occurs within the context of static or even contracting natural resource base.

Seeking the all-important fuelwood: an increasing human population eking out livelihood on a contracting natural resource base.

Increased conversion of dry-season grazing reserves into other land uses

There has been a recent trend towards conversion of traditional dry-season grazing reserves into other land uses. For instance, some dry-season grazing areas of the Maasai and the Boran have been expropriated by the State in Kenya as protected land (national parks and game reserves). The result is the inability of the pastoralists and their herds to access these sites, which are especially important during the dry seasons. Additionally, there have also been localized land-use changes: farmers have occupied a major livestock migratory corridor along the Tana transect in Garissa District, Kenya, denying access to the river for herdsmen and sometimes causing violent conflicts.

A goat browsing a tree (left). The area is degraded, and there is sparse groundcover. Multiple-use trees such as Baobab (right) may be the panacea to this kind of degradation.

Increased land privatization

In some parts of the eastern Africa region, such as Kenya and Tanzania, land adjudication has been carried out in some parts of the drylands. This process has been well advanced in the higher potential rangelands, shutting out the drier parts. The primary motive for this move towards individualization of land ownership was to give incentives for natural resource conservation. However, this has resulted in unforeseen problems. Firstly, this policy has meant that pressure could be taken off the arable parts of the drylands, where population growth had been phenomenal, so that landless farmers from the arable areas could venture into marginal areas, where hitherto insignificant farming was taking place. The result has been reduced returns on agricultural investment for the marginal farmers and environmental problems in the farmed areas. Secondly, the land adjudication process has been followed by the new owners fencing off their land. This resulted in the closure/interruption of wildlife migratory routes/corridors.

Land-use changes in water catchment areas

Land-use changes in the major water towers/catchments in the higher rainfall highlands of the region have a direct bearing on the livelihoods and economy of the drylands. For example, the Mt. Kenya highlands serve as the major water catchment for the Tana River. Agricultural activities in this important water catchment have undergone major changes, mainly on account of population explosion. Expansion and intensification of agricultural activities in this area has had implications for the people living downstream, in terms of increased soil erosion and sedimentation in the rivers: there has been a concomitant increase in sediment loading in the rivers and increased alluvial deposits in the rivers' deltas. Increased water extraction for usage in the highland water catchments also result in reduced downstream dry season flows. The population increase in the highland areas has forced some farmers to take up farming in marginal areas like Kitui, Kajiado, Narok and Baringo among other districts in Kenya.

Insecurity, conflicts and displacement of pastoralists

Some parts of EA drylands have witnessed civil strife. Competition for land use by different ethnic groups has resulted in one group or the other being displaced. Insecurity, together with the attendant fleeing and displacement, has meant that areas are cleared of human and livestock habitation for sometime. The people and their herds congregate in areas deemed safe havens that become overpopulated leading to the destruction and degradation of the environment. However, the vacated areas may witness range recovery and vegetation regeneration.

Disruption of the soil and hydrologic cycle

Poor grazing practices coupled with an intense extractive economy in EA drylands have contributed to reduction in the vegetation cover, reduction of palatable flora stands, destruction to soil micro-organisms, soil crusting and compaction and enhanced rates of soil and water erosion. Disorganization of the dryland vegetation structure is exacerbated by the loss of the surface topsoil where the soil nutrients are concentrated, even if it is the loss of just a thin layer. Livestock grazing used to be managed traditionally to avoid loss of grazing areas and reserves, but with the void created following the attrition of the ancient regulatory systems, soils have been severely affected. The results have been reduced water infiltration and concentrated runoff, leading to accelerated erosion and floods.

Soil crusting is a common feature in the drylands of eastern Africa.

One of the key problems facing eastern Africa drylands is soil erosion. Soil, for all practical purposes, is a non-renewable resource. The processes of soil formation take eons and ages, but the rate of soil degradation in the drylands is phenomenal. Billions of tons of topsoil are lost annually. In Ethiopia, for instance, an estimated 1 billion tonnes of valuable topsoil is lost annually. This massive problem is coupled with the exploitation of woodland resources and invasion by colonizing weed species such as *Prosopis juliflora*. As a result of these (and other) problems, the phenomenon of 'dust bowls' has become a common occurrence in EA drylands.

Air quality problems

EA dryland forests are to be found in small patches in key production areas, along watercourses (riparian zones and at higher elevations). More desertic formations of scrub-land are to be found in the more arid areas. Due to a mix of tree-less landscapes and high-velocity winds, people in the drylands are encumbered with increase prevalence of particulate matter in the air. This poses immense health problems.

Loss of biodiversity

Biodiversity conservation is an important element in resource management planning. This especially holds true for rare and endangered species. Habitat loss and fragmentation are among the most important causes of loss of important dryland biodiversity. Mature dryland ecosystems support a unique assemblage of species, some of which are endemic to the drylands, ranging from micro-organisms, such as bacteria, to birds. This is very apparent in riparian areas and river deltas, such as the Tana Delta.

A giraffe (left) and zebras (right) in a national park in Kenya. Wildlife biodiversity is abundant in the drylands of the region.

In the EA drylands, biodiversity, both flora and fauna, is threatened by both human over-extraction, habitat fragmentation and changing climates.

Invasive alien species

In the late 1970s and the early 1980s, the EA drylands witnessed the introduction of various alien species. The aim was to introduce alien species that were primarily effective in controlling soil erosion and soil and riverbank stabilization. Preference was given to those species that had other uses, such as firewood. For example, the *Prosopis* species were introduced in Kenya. The problem is now also afflicting the ‘Afar and Somali regions of Ethiopia. Subsequently, pastoralists have been adversely affected by the negative effects of these fast-growing, prolific species on vegetation and livestock.

Agroforestry systems in the region's drylands

Agroforestry practices are major features of the land-use systems in the drylands of Eastern and Central Africa. Trees are used for a variety of purposes in both cropped lands and in livestock grazing systems. Trees in the land and homestead find various domestic and commercial applications for both wood and non-wood products.

Tanzania

In Tanzania, nationwide afforestation campaigns were launched in the 1960s within the context of the 1967 Arusha Declaration, with the emphasis being on energy woodlots in all the climatic zones of the country. The main goal of the programme was to meet the rural energy needs of Tanzanians, but the aim has not been satisfactorily met in dryland Tanzania (Mbwambo 2004).

ICRAF has been involved for two decades in the introduction and dissemination of suitable dryland agroforestry practices in Tanzania. Rotational woodlots, improved fallows, fodder banks and relay cropping systems have been tested in the country's rangelands, especially in the Miombo woodlands.

Uganda

Uganda's drylands, straddling the area commonly known as the 'cattle corridor', occupy an area of about 84 000 km^2. Some of the problems affecting the Uganda drylands have been cited as overgrazing, deforestation, inappropriate farming systems, land and tree tenure and bush burning (Kakuru et al. 2004).

The policy framework for institutionalization of the concept of agroforestry in Uganda is in place. The Government's Plan for the Modernization of Agriculture (2000), the Forest Policy (2001) and the National Forest Plan (2002) all are supportive of the promotion and adoption of agroforestry as a strategy for poverty alleviation.

Ethiopia[1]

Agroforestry in Ethiopia is an age-old tradition. The indigenous agroforestry systems that are in operational in the country are a mix of silvopastoral and agrosilvopastoral systems. Ethiopian drylands account for more than two-thirds of the total landmass.

The concept of natural regeneration/rehabilitation by means of enclosure areas is common in many parts of Ethiopia, especially in northern Ethiopia (Gebrehiwot 2004). The local community is involved in delineating the boundaries of the enclosure area. Care is taken to

[1] This section draws heavily on "Dryland Agroforestry Strategy for Ethiopia," a paper presented at the Drylands Agroforestry Workshop, held in September 2004 at the World Agroforestry Centre (ICRAF), Nairobi.

ensure that the enclosure area is not close to settlements. Guards are recruited for protection and care of the enclosed area; nominations for the job are done by the local people.

Another concept in northern Ethiopia (Tigray region) is the hillside distribution system, in which communal hillside plantations in degraded elevations are planted with eucalyptus and set aside as pasturelands. Individual planting of trees was adopted as the mode of replanting the hillsides. This system has been in operation for over a decade now, and has been adopted by the Tigray Regional government through the Bureau of Agriculture and Natural Resources as a means of allocating land in degraded hillsides to landless members of communities.

Apart from providing critically needed fodder for livestock, enclosure areas are also important in conservation of dryland biodiversity. Two main reasons have been advanced for the relative success of enclosure areas in northern Ethiopia: one, the appreciation that degraded lands in themselves are poor in forage production, and, two, the system requires little initial investment and maintenance, especially when compared to community plantations (ibid.). However, community understanding and acceptance of the need to keep off the enclosure area until after full regeneration is an important pre-requisite for long-term success.

Successes in dryland agroforestry

West Pokot in Kenya[2]

The Pokot community in the north Rift of Kenya practice a mixed land-use system, combining pure pastoralism in the drier zones with cultivated agriculture in the better-watered key production areas.

The West Pokot district has been experiencing the effects of severe land degradation and desertification, caused by a mosaic of factors (including increasing human and animal population and contracting natural resource base). An international non-governmental organization, Vi Agroforestry, introduced the concept of agroforestry in the district. The organization targets small-scale farmers, and focuses on increased food security, energy security and wealth creation.

Because of the widespread loss of tree biodiversity, Vi Agroforestry began re-vegetation of bare, denuded landscapes with trees. Land rehabilitation was seen as a method of land management through soil conservation and tree planting. The community was initially sceptical about the idea of enclosure areas, since it had lost land to the State when the

[2] This section is based on a paper by Vi Agroforestry Project on "Participatory Extension Strategies for Promoting Agroforestry in the Drylands of West Pokot, Kenya," presented at the European Tropical Forestry Research Network's (ETFRN) workshop on 'Rehabilitation of Degraded Lands in Sub-Saharan Africa: Lessons from Selected Case Studies'

government had broached the same idea. To overcome this initial hurdle, Vi Agroforestry opted to use institutions at first, such as schools and hospitals, which had degraded landscapes. These were used as demonstration sites. The pastoralists thereafter were convinced of the practicality of the approach and adopted the technology, with some approaching the project for help in starting up their own enclosures.

The project operates a technology dissemination system that is hinged on application extension tools such as participatory rural appraisals (PRA) and community action plans (CAP). These tools are used for community-based diagnosis and prioritization of the felt needs of the community as well as planning the implementation schedules and frameworks of the suggested interventions. Both tools enhance the participation of farmers and pastoralists in agroforestry programmes.

For proper coverage of project areas, Vi Agroforestry has adopted a concept called 'Area of Concentration Approach' (AoCA). An extension agent is stationed in an area where the agent works with 200-350 farmers/pastoralists for up to five years, depending on the community enthusiasm. The result of this is that the community's capacity for sustaining agroforestry technologies and practices is enhanced.

Other technologies promoted, as addenda to agroforestry, are apiculture and soil fertility improvement. Some spin-off benefits from enclosure areas include the evolution of individualization of land tenure, reduced nomadism and improved animal health as well as increased enrolment in schools. Higher livestock production has also been reported.

Vi Agroforestry credits the success in West Pokot to its policy of cooperation with the people and local development partners. The project has been structured in such a manner as to be responsive to the spontaneous, unforeseen but vitally important demands and needs of the community in which it is working.

Ngitiri system in the Tanzanian drylands

The Ngitiri[3] system refers to a system of 'bush fallow' management used by the Sukuma people of Shinyanga region in northern Tanzania, the largest ethnic group in the country. Areas of grazing land, which have been 'closed' to livestock, by the village council, or a private landowner, are called 'Ngitiri' in the local language; this is an example of an indigenous silvopastoral technology for land rehabilitation. They are regarded as dry season fodder/grazing reserves.

There are two Ngitiri set-ups: private and communal. The private Ngitiri is owned by a landowner, and is located in homesteads along lowland riverine zones as well as on-farm; the communal one belongs to the village community and is bigger in size and extent. As may be

[3] Sometimes, this system is also referred to as Ngitili.

expected, farmers use the communal Ngitiri after which they fall back on the private Ngitiri, especially in the dry season.

The primary importance of the Ngitiri system is in fodder production, with some authorities estimating fodder production of up to 4 t DM/ha for the traditional Ngitiri and 8 t DM/ha for the improved systems (Kitalyi et al. 2004). In terms of crude protein (CP) values, the system is impressive, with potential CP values of up to 300 kg CP/ha being realized from an improved Ngitiri (ibid.). The system has the potential too for improving site ecology; trees enrich soil surface through litter fall decomposition and mineralization (ecosystem/environmental services). Extensive ground cover in the enclosed area helps in ameliorating and reducing soil erosion in the drylands, both water- and wind-based. Weight loss in animals, especially among young growing animals, is minimized.

Shortages of fuelwood and fodder is minimized too, meaning that there is less dependence on rangeland resources and hence attendant over-extraction is reduced. This system provides a basis for the development sustainable silvopastoral agroforestry in a dryland setting (Mugasha et al. 1996). Indigenous technical knowledge (ethnoscience) also has also played a part in acceptance of such related technologies such as fodder banks and improved fallow systems (Maro 1995). Health and nutritional security are also mentioned as some of the other spin-offs from the Ngitiri system (Kitalyi et al. 2004).

The interesting aspect about the Ngitiri system is that it is a farmer-led and farmer-managed initiative that has evolved after years of traditional grazing management. However, the system is confronting a number of constraints, prime among them land laws' restrictions, declining land availability and increasing land insecurity, resource use conflicts, fire hazards and low quality dry season fodder as a result of the non-availability of quality fodder tree species.

Drivers of successful rehabilitation of degraded drylands

Apart from committed, sustained and proactive community participation in the project cycle, other drivers of successful dryland rehabilitation programmes in denuded landscapes have been identified (Blay 2002):

- There should be some short-term benefits, whether monetary or material, in addition to anticipated future beneficial impacts;
- Local people's attitudes, behaviour and perceptions should be in line with the principle of the rehabilitation programme – the people have to accept and internalize that change will be in the long-run be to their advantage;
- Comprehensive understanding of the interconnectedness, peculiarities and complexities of dryland ecosystems, especially dryland forests and woodlands;

- Rehabilitation should lead to improvements in soil fertility, hydrological processes, etc;
- Existing land uses should be analysed, and land attributes should be matched with land uses so as to determine drivers of degradation;

Criteria and indicators of successful dryland rehabilitation

Blay (2002) has developed a criteria-and-indicator system for measuring the successes or otherwise of dryland rehabilitation programmes.

Criteria

Criteria	**Query**
Can the system be sustained?	Is the new system self-perpetuating or must it be subsidized to maintain itself?
Vulnerability to invasions	Does the new community resist invasion by other communities?
Productivity	Is the new system as productive as the original?
Nutrient retention	How efficient is the nutrient cycling?
Biotic interactions	Are all key animals and plant species present?

Source: Blay, 2002.

Indicators

Blay has developed two sets of indicators, biophysical and socio-cultural, for measuring the success or failure of rehabilitation. For the two indicators, the stability, efficiency and flexibility of the new eco-setting are established.

	Biophysical indicators	**Socio-cultural indicators**
Stability	Stability of the soil surface	Stability of human population
	Presence of adequate plant cover and growth	Stable market prices
	Adequate crop yield	Adequate food
	Appropriate plant species composition and structure	Stable land-use pattern
	Appropriate animal population	Stable land tenure system
	Adequate regeneration or reproduction of preferred species	Appropriate balance between subsistence crops and cash crops
	Acceptable water quality (surface and groundwater)	Stable rate of fuelwood consumption
	Appropriate albedo	Stable rate of water use
Efficiency	Need for seed/fertilizer inputs	Level of public involvement or participation in the programme
	Need for weed control	
	Need for irrigation	
Flexibility	Extent to which alternative or multiple uses can be made of the land	Extent to which economic flexibility is possible; accumulation of income wealth

Source: Blay, 2003.

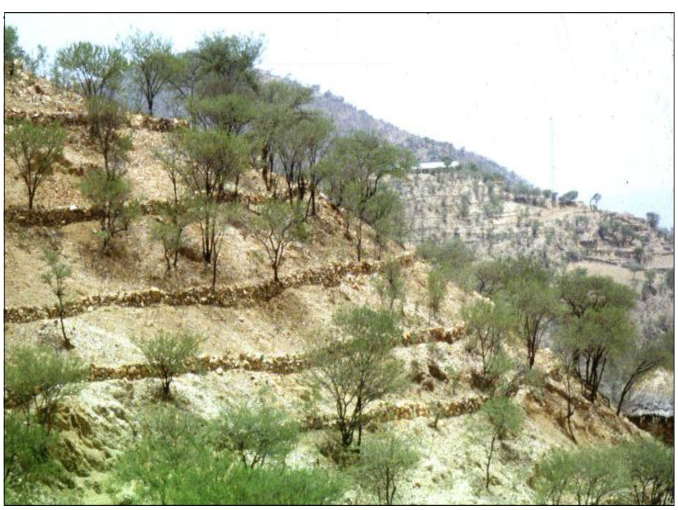
Experiences from India

The drylands of India occupy an area of more than 3 million hectares. Like other drylands, they suffer from inherently low productivity due to low rainfall, high evapotranspiration and excessive wind-speeds (Harsh and Tewari 2003).

In the hyper-arid zones of India, the main mode of livelihood is livestock-based. The predominating grass species is *Lasiurus sindicus*; there are also scattered shrubs and trees. This grass species is productive even in seasons of low rainfall, providing 20–30 quintals of dry fodder per hectare: if reseeded properly, the productivity per ha can increase to between 40–45 quintals. By planting a leguminous tree species in between rows of the grass, the nutritive value of the grass can be increased, improving livestock production (Ibid).

Sand dunes are a feature of the Indian drylands. The Central Arid Zone Research Institute (CAZRI) has developed agroforestry systems meant to stabilize sand dunes, arrest the spread of desertification as well as provide increase economic returns on investments in sand dune stabilization. In sand-dune stabilization, CAZRI recommends *Acacia tortilis*, planted at a spacing of 5 m x 5 m. The trees can also be planted in belts of rows of trees, leaving a space of 50 m between the belts. Crop cultivation is also possible in this arrangement (Kavia and Harsh 1991). Other trees with commercial prospects such as *Acacia senegal* and *Acacia seyal* can be used for sand-dune stabilization, thus roping in the added advantage of income from sale of gum arabic.

In areas with low rainfall (between 150–300 mm), legume crops are grown in association with *Acacia senegal*. CAZRI has developed gum arabic exudation techniques (Khan and Harsh 1994) which, when adopted by tappers, double the incomes they realize from traditional systems of gum exudation (Harsh et al. 2000).



Rehabilitating a degraded hill-slope in Ethiopia: farmer innovations need to be integrated into land rehabilitation initiatives.

The World Agroforestry Centre experiences

The Sahel

The Sahel programme works with the national agricultural research systems (NARS) in Mali, Senegal, the Gambia, Niger and Burkina Faso in the use of participatory approaches that place scientist, farmers and development agents in a co-knowledge creation and dissemination process, capitalizing on farmers' expertise and their knowledge sharing strategies.

Effective information dissemination pathways are being identified and used to accelerate the dissemination and adoption of promising agroforestry innovations and technologies. Activities take place within a research-development continuum that links environmental protection with food and nutritional security and increased farmers' income, as well as connecting local and global issues. The programme helps to strengthen the capacity of institutions and individuals to undertake agroforestry research, development and education.

The major thrusts of the ICRAF Sahel programme is scaling up the use, adoption and impact of agroforestry based innovations; soil fertility improvement for enhanced crop and high value agroforestry tree species productivity and increased farmers' incomes; and capacity building and agroforestry education.

Agroforestry contribution to sustainable land use in drylands

Drylands typically suffer from unsustainable land uses that have evolved in the recent past. An example of such land use that is gaining momentum is farming in marginal areas. Although some semiarid lands can sustain limited-intensity farming, this needs to be tempered with mechanisms that will make this sort of land use more sustainable in the long term and contribute to the resilience of the land. Sustainable land uses are those land uses that produce public goods and services for consumption by the people while at the same time ensuring the protection of the natural resource base upon which those particular modes of production or land uses are anchored.

Sustainable land use

Agroforestry can contribute to the evolution of sustainable land use in EA drylands. This is possible because in the first place agroforestry as a concept was mooted, and evolved, with core concerns about ecological and economic sustainability – resilience of environment, diversity of income. It is a system that blends production (food and income security at household- and community-level) with ecosystem services.

Dryland Agroforestry is aimed at **increasing diversity of options** available for mitigating the impacts of changing ecological circumstances and worsening economic environments, and is more stable than, for instance, mono-cropping or livestock rearing alone. It is an option that results in better usage of available energy and monetary resources, better usage of available moisture, nutrients and space. There are also other added advantages such as cleaner waters in rivers and lakes, an effect that results from the water purification potential of some trees. This can be useful in sewerage systems of municipalities that suffer from sewerage disposal problems.

Agroforestry can also assist in enhancing the resilience of dryland environments. Land uses in drylands are generally determined by the prevailing environmental conditions. A high premium is usually placed on the degree of resilience of a particular ecosystem. Due to the fact that agroforestry systems have more than one production component and are complex in terms of structure and functioning, they are more resilient than most of the prevailing modes of production. Because there is a diversity of tree and shrub species involved, the vulnerability of one species to environmental stresses such as pests and insect attacks is more than offset by the functioning of the other species. The trees and shrubs can also reduce the over-reliance of animal production systems, giving the land more time to fallow. In the same light, the number of persons exposed to the vagaries of nature such as droughts and famine are reduced. By combining woody perennials with forage and food crops, arid and semiarid areas that are too fragile for sustainable, intensive mono-cropping systems can produce food for human consumption, forage for livestock as well as meet the energy needs of households.

Dryland agroforestry does not operate in a vacuum. It complements other land uses. For example, it can combine very well with the main existing land use in the drylands: nomadic pastoralism. Once the herdsmen have been educated on the implications of increasing the primary productivity of the rangelands through the mechanism of agroforestry, they will be more than willing to try this option out, as demonstrated by the West Pokot experience. For purposes of management of watersheds and water towers, agroforestry offers the prospect of both on-site (e.g. soil fertility management and soil conservation, increased infiltration capacities of soils, reduced surface runoff and reduced erodibility of soils) and downstream benefits (positive effects from reduced surface runoff, stabilization of streamflow because of reduced runoff, reduction in sediment loads of water bodies, water purification capacities of trees, which absorb nutrients and sometimes pesticides and other agro-chemicals, including heavy metals that would otherwise cause water resource pollution).

Improving livelihoods in the drylands: Agroforestry options

Eastern Africa dryland inhabitants are among the poorest in the world, suffering from basic lack of information on the options for sustainable livelihoods in their areas. The low primary productivity of the drylands is sometimes misconstrued to mean that they are resource-poor. There are a number of Agroforestry options that are available for the purpose of both resource conservation and economic development (the ‘integrated conservation and development’ – ICAD – approach).

Gum Arabic – an avenue for economic empowerment

Gum arabic is a water soluble resin exuded by the barks of several species of the acacia tree, especially *Acacia senegal*, and used in the manufacture of adhesives and ink, and as a binding medium for marbling colours. Historically, gum arabic was used to increase the viscosity of ink, or to make it flow well, to prevent it from feathering, and to suspend the colouring matter. Other uses of the gum include emulsification, as flavouring agent, as thickener, surface finishing agent, sugar industry (retarding sugar crystallization) as well as in the food industry (confectionary, beverages, flavour encapsulation, brewing). In addition to all this, this tree has other added advantages: it is a nitrogen-fixing species, it can be used in re-vegetation of degraded and denuded landscapes, and it is useful for sand-dune stabilization/fixation and control of wind erosion (a feature too common in our arid lands).

The usage of gum arabic can be traced as far back as 2650 BC. The best quality gum usually comes from exudates from *Acacia senegal*: this species is also the main source of commercial exports. Gum from *Acacia seyal* is not approved for food-related use in Europe and the US and hence is mainly used in the production of non-food products. Kenya can produce anything up to 4000 tonnes, earning Ksh 1.4 billion in a good year when a tonne fetches the premium price of US$ 4500.

Acacia senegal is a small scrubby tree usually found well distributed in the drylands of Eastern Africa that produces a very important product. Farmers in neighbouring Sudan are reported to be earning about Ksh 4 billion (US$ 50 million) annually from the export of gum arabic. According to the Bank of Sudan in its annual report for 1999, 30,000 metric tons of gum arabic was exported in that year.

This tree is a leguminous, nitrogen-fixing tree that is a pioneer species which thrives on sandy soils receiving between 150 and 850 mm of rain a year. Mature trees, 5 to 6 m high and 5 to 25 years old, are tapped by making incisions in the branches and stripping away bark to accelerate exudation. The gum dries into shiny, amber-coloured globules, which are manually collected. The exudation may be a physiological response to various environmental stress factors, such as high temperatures, cuts made into the bark, insect wounds. Collection takes place at intervals during the dry season. However, a drawback would be the fact that the yield from each tree rarely exceeds 300 g per harvest, but higher and more regular yield can be induced by tapping the tree at precise periods during the dry season. The colour and quality of the gum exudates depend on the climatic and soil conditions of the area. Some studies have shown differences between Kenyan gum arabic and gum from other countries such as the Sudan and Nigeria in terms of specific rotation, mineral (especially nitrogen) and metal content and viscosity. These differences may have evolved as a result of the differences in edaphic (soil) and climatic factors.

Although there are a number of synthetics that have been developed (and which are posing a threat to the natural gum), yet gum arabic exceeds all synthetic imitators in the quality of emulsions it forms. Produced by nature, gum arabic is 95% soluble fibre (calculated on a dry basis). Unlike synthetic additives, gum arabic is labeled in the United States as "ADI Not Specified", allowing unlimited use in food products. This is an opportunity waiting to be taken advantage of, more so given that the US Government recently passed legislation which was drafted to provide impetus to African economic growth: the African Growth and Opportunity Act (AGOA). Indeed, the government of Uganda and the Coca Cola Company were at one time engaged in discussions that would have seen the construction of a gum arabic factory in the country: the project involved the establishment of quality-control laboratories, setting up of gum arabic collection centres, gazetting of trees and capacity building (training) of people willing to engage in the business. The thrust of the business was to benefit from AGOA Act.

In Kenya, the Gum Arabic and Resins Association (GARA) was formed in 1997, through support from the German Technical Cooperation (GTZ). GARA is responsible for promoting and developing the gum arabic and resins industry in the country. With members from various disciplines, including farmers, pastoralists, technocrats, exporters and importers of gum as well as researchers, the Association has been in the forefront, highlighting issues important to the industry. It holds consultative meetings where pressing issues are discussed. One of the tasks GARA had set itself includes the establishment of a database of stakeholders in Kenya's gum industry. Regionally, the Network of Gum Arabic and Resins Associations in Africa (NGARA) plays an important role in promoting the sustainable use of the continent's gum arabic resources.

Sudan dominates world trade in gum arabic, controlling 60% of the market. It also produces about 80% of the world's gum arabic. Other countries that are engaged in the gum business (labeled the 'gum belt' countries) are Nigeria, Cameroon, the Sudan, Mali and Chad. The Sudanese are also engaged in research so as to engineer a variety that will be more drought-tolerant and which will bear higher yields and more consistent gum quality.

The Sudanese government controls and regulates the gum industry, especially in quality control and the grading system of the Sudan is used as an industry standard. The two main grades are 'Hand-Picked-Selected' and 'Cleaned.' In this regard, there is evidently a lot to be learnt from the Sudanese government in dryland development and management. Apart from the gum industry, it is also way ahead of Kenya in regulating its charcoal industry (as a recent ICRAF mission to that country discovered).

According to a private sector player, Kenya's gum is not able to attract premium prices because of problems relating to quality, both inherent (such as the gum's high viscosity, which affects its optical rotation properties and hence renders it unsuitable for use in the pharmaceutical industry) as well as external (such as adulteration, impurities e.g. dust, etc). The gum also contains a lot of impurities, including dust from transportation of the gum on the road ('poor packaging'); the dust becomes embedded and difficult to remove. As a result, exporters have to spend a lot of money (about 20% of their costs) cleaning the gum, eating into producer prices and profits. Harvesting of gum with the tree barks represents another problem.

Kenya annually produces/exports 150 tonnes of gum Arabic[4]. This low volume has been attributed to a number of problems, including the ones already cited. An important, substantial buyer would have been the pharmaceutical industry in Kenya, but because of the high viscosity problem, the drug companies in Kenya are buying their stocks from their parent companies in Europe. The quality of the gum Arabic can only be controlled effectively

[4] Per. comm. with Managing Director of Elegant Trading Co, December 2004

enough at the point of harvesting. There is, therefore, need for producers to be educated on this. Continuity and consistency of this producer education is important too.

The constraints to the development of a gum industry in the country would appear to be the lack of appreciation of the value of the tree as a very valuable resource. In addition to this, quality problems (as a function of site and location of the tree) may also count towards lower quality gum. The reports that gum arabic from Kenya and Tanzania is dark red in colour instead of the usual amber colour (perhaps because of the uncommonly high content of iron) would appear to exclude the gum from usage in certain processes. Kenya's gum arabic has high nitrogen content (0.44%) while the FAO specifications state that nitrogen content should be between 0.27 and 0.36% for commercial uses, especially food purposes: this is an issue that may be addressed through bio-engineering.

Managing alien species invasion – the case of Prosopis[5]

Prosopis juliflora is a perennial deciduous thorny shrub or small tree that can grow up to 10 m tall, with a trunk up to 1.2 m in diameter. *P. juliflora*, *P. pallida*, *P. chilensis*, *P. alba*, *P. pubenscenes* and *P. tamarugo* are all species that are native to the Americas, but have now become established in arid and semi-arid regions of Africa and Asia. *Prosopis cineraria* is native to India. Common English names for *Prosopis juliflora* are mesquite and honey mesquite. Prosopis are fast growing, salt tolerant and drought tolerant tree species that can grow in areas receiving as little as 50 mm of rainfall per year.

However, there is great controversy about this species in many parts of eastern Africa. The main bone of contention is that if left unmanaged it often colonizes disturbed, eroded and over-grazed lands, forming dense thickets that are difficult to penetrate. Thickets of Prosopis have become established in grazing lands, crop lands and along river courses, alarming pastoralists, farmers and conservationists. There is concern about the impacts of the tree on biodiversity of native plants and the amount of water in dryland streams. Prosopis species have been declared noxious weeds in many countries, including Australia, Argentina, South Africa, Pakistan and Sudan. On the other hand, Prosopis has been shown to be useful in restoring degraded and saline lands, producing a variety of useful products for the local populations. It has proven to be a most important source of fuelwood for the poor. The tree has potential as a source of fuelwood, timber, honey and animal forage.

Prosopis was first introduced in Africa in 1822 in Senegal; subsequent introductions into Africa were in South Africa (1880) and Egypt (1900). The first documented introduction of the tree into Kenya was in 1973, when seeds were imported from Brazil and Hawaii for rehabilitation of quarries in the saline soils near the city of Mombasa. In the early 1970s, it was introduced in the Hola Irrigation Scheme in Tana River for purposes of controlling soil erosion. Then, in the early 1980s, it was introduced into the Bura Irrigation Scheme as well as in Baringo. The main species introduced to Kenya were *Prosopis juliflora, P. chilensis, P.*

[5] This section is based on article by Zeila et al. appearing in *The Prunus Tribune*, an ICRAF newsletter.

pallida, P. alba, P. pubenscenes and *P. tamarugo*. The districts most affected by this species in Kenya are Garissa, Wajir, Mandera, Baringo, Turkana, Taita Taveta and Tana River.

Twenty to thirty years after its introduction to the drylands of Kenya, there now is increasing concern and debate about the negative impacts of Prosopis and the possibilities for its control and/or eradication. Newspaper headlines have been made in recent months about holding various agencies accountable for the negative impacts of the tree. The Kenya Forestry Research Institute, the Forestry Department and the Food and Agricultural Organization organized an information-sharing workshop on Prosopis in October 2003 at which a number of complaints were received from the residents of Baringo, Tana River and Turkana districts. Local residents complained about the species' powerful and poisonous thorns, its aggressive colonization of useful habitats such as pastures and irrigation/farming/fishing areas, its negative effects on animal and human health, and its use as a hideout by cattle rustlers and wild animals. Many people in the drylands are calling for its eradication. Yet the experience from other countries shows that Prosopis is extremely difficult and costly to eradicate once it gets established. A more effective and sustainable solution in such areas might be more effective management through utilization and harvesting of marketable products.

Fast-growing, drought and salt-resistant, and with remarkable coppicing power, Prosopis is a natural fuelwood candidate that can be used in meeting the energy requirements of the arid and semiarid lands of the country. With specific gravity 0.70 or higher, the wood has been termed "wooden anthracite", because of its high heat content: it burns slowly and evenly, holding heat well. Many residents in North Eastern Kenya, for instance, are already using prosopis charcoal because of the above-stated qualities. The wood of Prosopis is an important source of fuelwood for millions of people in the drylands of the world. It meets, for instance, 70% of the energy needs of the people of Haiti, where it supports the livelihoods of 150 000 people annually in addition to generating US$50 million income annually; it also meets more than 70% of the energy needs of dryland India.

The Indian Forestry Department produces and markets Prosopis charcoal through special development corporations. For example, in the state of Gujarat, an estimated 3 million tonnes of charcoal is produced yearly, creating 55 500 man-days of employment during the same period. It is also possible to generate electricity by burning the wood of Prosopis: this can be utilized in areas that are off-grid, especially rural ASAL areas. Energy from Prosopis can be a useful complement to other potential off-grid options in the ASALs of Kenya like solar and wind energy. For local residents of Kenya to garner more of the potential energy benefits of Prosopis juliflora, there might need to be changes in the policies and bureaucratic procedures that govern the production and marketing of charcoal.

Tests conducted by ICRAF in three dryland districts in Kenya have established the potential for producing good quality charcoal from prosopis trees as well as the possibility of uptake of charcoal producing techniques, such as the inexpensive 'Casamance' mount kilns, by charcoal burners. The country's forest authorities are also considering legalizing charcoal production using prosopis trees.

Prosopis wood has excellent structural stability, making it ideal for the manufacture of furniture and handles of agricultural implements. The Kenya Forestry Research Institute (KEFRI) has conducted studies, at its Forest Products Resource Centre, Karura, into its usability in this regard. The pods of Prosopis are sweet, nutritious and are consumed by mammals, birds, insects and reptiles. Although there are low concentrations of unpalatable chemicals such as tannins and polyphenols, the pods contain nearly all the essential amino acids in standard quantities set by the FAO and the WHO.

Prosopis flower is an important source of nectar and pollen. This is important in apiculture, as the native pollinators are attracted to the bright colours of the Prosopis flowers. High quality honey is produced as a result. The exudate gums from the trunk and branches of its trees can be used in various sectors: food, pharmaceutical, chemical and manufacturing industries. Other Prosopis products include tannins, dyes, medicine, live fencing, shade, soil stabilization and carbon sequestration.

Prosopis has potential uses in the wood carving industry (where the wood can be used to produce high-quality carvings), flooring parquettes/tiles, high-value furniture, fibre boards and railway cross-beams. It is rarely used in large-scale construction, however, because most trunks are not straight or long enough. The bark (rich in tannin) can be used for roofing and the gum (which forms an adhesive mucilage) can be used as an emulsifying agent as well as in confectionary and mending pottery. Prosopis is a folk remedy in some arid zones of the world for catarrh, colds, diarrhoea, dysentery, excrescences, eyes, flu, colds, hoarseness, inflammation, itch, measles, pinkeye, stomach ache, sore throat, and wounds.

Promoting fruit tree farming in drylands

A measure of fruit tree farming is practiced in the drylands of eastern Africa. However, because these farming systems are located in marginal areas, the farmers have not been able to attract the technical backstopping support required. ICRAF has ventured into fruit farming in the drylands of the region, in collaboration with national partners, both State and non-State actors.

Fruit tree farming can achieve at least six of the eight Millennium Development Goals (MDGs):

- No 1 – Eradicate extreme poverty and hunger: can be met through fruit trees providing nutrition and avenues for enterprise creation and development
- No 3 – Promote gender equality and empower women: through granting women usufruct right to fruit trees and establishing women-run and women-managed fruit tree-based enterprises

- No 4 – Reduce child mortality: by the availability of more vitamins from fruit trees to vulnerable sections of the society such as children
- No 5 – Improve maternal health: availing nutrient-rich fruits to expectant and nursing mothers
- No 6 – Combat HIV/AIDS, malaria and other diseases: achievable through providing vitamins to counteract the threat of opportunistic diseases in HIV/AIDS patients
- No 7 – Achieve environmental sustainability: through ‘greening’ land

However, as a recent ICRAF study on constraints to mango production and marketing in dryland Kenya found out, fruit tree farmers suffer from a number of problems, including, among others, pests and disease management, germplasm limitations, wastage and loss of produce through lack of access to shelf-life extending technologies, poor/unsatisfactory markets, poor extension services, transportation problems and generally poor infrastructure.

Opportunities and constraints in dryland agroforestry extension

Opportunities for extension of agroforestry practices into dryland areas have been given a boost by the enactment of enabling policies and legislations. In Uganda, for instance, the Plan for the Modernization of Agriculture (PMA) recognizes agroforestry as an option for enhanced agricultural productivity. Problems that are usually encountered in agroforestry interventions are many and varied, but one main problem is water. Drylands are usually water-stressed environments, meaning that agroforestry has to go hand-in-hand with water harvesting, especially rainwater harvesting. Another hurdle is the **antipathy** to trees by some dryland communities, fuelled in part by past experience with colonizing invasive species and trees known as habitats for tsetse fly and other disease vectors. Trees that cause a lowering of the water table will also not be accepted. Secondly, if there are **no incentives** for adopting agroforestry practices or for maintaining rehabilitated dryland forests (e.g. as in when there is abundant firewood and hence no pressing energy needs), agroforestry will be hard pressed to succeed. Another hurdle is the issue of **land tenure** and **usufruct rights**. A good percentage of land in EA drylands is classed as State or Trust land. Thus, land management/rehabilitation programmes must contend with the seemingly dual ownership of the land: the pastoralists have *de facto* ownership of the land, putting it to their chosen land use of pastoralism; the State’s laws claim ownership. The **pastoralist nature** usually makes it hard for pastoralists to tend to planted trees; this is, however, not much of a problem when agroforestry involves tree species that do not require sustained/continuous care. These constraints impose some limitation on the goals, objectives and the orientation of agroforestry programmes in the drylands. For instance, the programmes should occur in the context of engendered proactive local participation, in which benefits of a short-term nature, such as fodder for livestock and potential for meeting energy needs, are envisaged. In any agroforestry intervention, special emphasis needs to areas of depleted woodlands and drylands. Particular prominence also needs to be given the role of refugees and other in-migrants into the EA drylands. Natural regeneration should be allowed to go hand-in-hand with enrichment planting in areas of depleted woodlands, especially those laid bare by the refugee populations in Kenya, Uganda and Ethiopia.

Recommendations for future action

Economics

- Conducting an economic survey that identifies tax and regulatory disincentives to agroforestry extension in the drylands, if any, and quantify the economic impact of such disincentives on the livelihoods of dryland communities;

- Conduct detailed economic analyses of a variety of agroforestry options/potential available for adoption in the EA drylands, including initial establishment costs and risks as well as income potential under varying management options;

- Evaluate the income potential for selected commercial species such as *Acacia senegal* and *Tamarindus indica* in the light of other developing nations' experience (e.g. Sudan and India);

- Investigate the possibility of linking the exports of commercial tree species from agroforestry systems in the drylands to Fair Trade associations and companies in the developed world.

Policy and management

- Evaluation of forestry policies and their continued relevance for sustainable development in the drylands and their capacities to engender proactive community participation in dryland forest management;

- Reviewing the place of agroforestry in regional and national planning, especially in the poverty reduction strategy papers of the region's governments, the benchmarks for prioritization of poverty reduction mechanisms;

- Evaluation of policies in other sectors that may have a bearing on dryland agroforestry, e.g., subsidies for agricultural production;

- Evaluation of the implications of contemporary land tenure systems and land statutes for dryland agroforestry;

- Approach all land management challenges in the drylands from an ecosystem (holistic) perspective;

- Advocating for the recognition by development planners and the relevant authorities (e.g. economic planners and national environment management authorities) of dryland agroforestry as one of the most efficient and sustainable ways of land rehabilitation and land management;

- Undertake a comprehensive survey/census of useful agroforestry trees and agroforestry practices in climatic analogues of EA drylands, such as the Indian drylands;

- Institutionalization of policies for the sustainable utilization and co-management of dryland forests, with emphasis on making forestland, or part of it, available for dry season forage by the pastoralist herds; and

- Facilitating enactment of policies that will create an enabling environment for the emergence of a group of trades-people who specialize in alternative livelihoods, such as the gum arabic.

Education

- Advocating for the inclusion of dryland agroforestry as a taught discipline in the curriculum of schools and universities in the region, especially in the ASALs, with well-developed course materials;

- Development of dryland agroforestry extension manuals differentiated for use in the various dryland agro-ecological zones by specific user groups;

- Raising community awareness about the potential of agroforestry in raising their living of standards and income diversification, more so for improved livestock production; and

- Creating an agroforestry information programme/literacy packages in the print and electronic media.

Institutional

- Establishment of dryland agroforestry programmes within the overall structure of the national agricultural research systems (NARS);

- Development of a regional research centre that will be mandated to conduct on-station and on-farm trials for best-bet agroforestry innovations and techniques in addition to training personnel;

- Creation of an inter-country working group to improve the methodology and foundation of research strategies for dryland agroforestry systems.

Demonstration

- Establishment of regional demonstration stations with regard to windbreaks, alley cropping and pastureland agroforestry;

- Development of model trees-on-cropland/parkland system for increased uptake or take-off of agroforestry among the pastoralists and agro-pastoralists;

- Conducting short-term courses as well as facilitating farmer exchanges in the semi-arid areas;

- Demonstrate water-harvesting technologies in selected areas.

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