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Fire as a tool in the management of a savanna/dry forest reserve in Madagascar

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Abstract. The possible use of fire for the management of the Ankarafantsika Reserve in the northwest of Madagascar and of its surrounding area is studied. Within this savanna landscape large parts of the remaining dry forests still exist with a unique biotic diversity, both in terms of total number of species and endemism. Unfortunately, mainly man-induced uncontrolled fires threaten these forests.

Actual and former fire regimes of the local communities are analysed. The use of fire is an integrated part of land use and is also governed by socio-cultural traditions. The impact of fire on the dynamics of dry forests and grass savannas is studied considering the specifics of different fire regimes. We propose that a deliberate and controlled use of fire respecting the vegetation stage and the defined objectives could be an appropriate management tool. The strategy of a fire management is elaborated considering both the conservation of biodiversity and improvement of the livelihood of the local population depending upon the Reserve's resources. Obviously, a sustainable management of the natural resources requires a substantial participation of the community.

Keywords: Dry forest; Fire ecology; Natural resource; Savanna dynamics.

Nomenclature: Humbert (1936).

Introduction

Environmental destruction is widespread in Madagascar. Most of the original species-rich lowland rain forest along the East coast, the mountain forest of the Central Plateau as well as the dry forest in the northwest have been replaced by species-poor secondary savannas mainly dominated by grasses. Abusive and often uncontrolled fires have played an important role in the loss of the forest cover. The species loss is very dramatic, since more than 80 % of Madagascar's plant and animal species are (palaeo-) endemic – the island was separated 165 million yr ago (Anon. 1994). The unique biotic diversity asks for urgent conservation measures, but the protection of the endangered remaining ecosystems is a difficult endeavour.

This paper deals with a remaining savanna landscape on the Ankarafantsika plateau and its surroundings in Madagascar. It is found ca. 100 km south of the town of Mahajanga at the northwest coast (16° 15' S, 46° 55' E). The plateau is of Cretaceous origin and ca. 400 m a.s.l. It slopes off towards the northwest from the escarpment along the southeastern border. Coarse red and white sands dominate on the plateau. These soils are highly erodible especially if the vegetation cover is reduced. Large 'lavakas' (erosion gullies) occur adjacent to the escarpment. Under the influence of the northwest monsoon the mean annual rainfall is ca. 1300 mm (climate station of Tsaramandroso) with a prolonged dry season between April and November. The mean annual temperature is 27 °C. The climate type in the Koeppen system is Aw. Fig. 1 shows the climate diagram for Ankarafantsika according to the Gaussen system .

The Ankarafantsika plateau encloses a large part of the remaining dense, dry, deciduous forest. Formerly, a much larger area of the western domain of the phytogeograpical western region of Madagascar was covered by dry forest (Koechlin 1993). The plateau, with dry forests, is intersected by river valleys with semi-deciduous riparian forests (*Raphia farinifera*) of limited extension. Floristically rich dry forests (*Dalbergia* spp., *Albizia* spp., *Tamarindus indica*) vary in size with both thickets of less than 0.5 ha and large forests of 20 - 100 km^2. Within the dry forest patches of moist grass savannas exist, dominated by *Aristida barbicollis* and to a lesser degree by *Hyparrhenia rufa*, *Heteropogon contortus* and *Themeda triandra*. Only few savanna trees occur. The most frequent are *Acridocarpus excelsus*, *Hyphaene shatan*, *Ziziphus mauritiana* and *Strychnos spinosa*. In the landscape surrounding the plateau savanna formations with variable tree cover prevail.

Rice is by far the most important agricultural crop and the vast plain of Marovoay in the Betsiboka basin (downstream of Ankarafantsika) is the second largest rice-growing region in the country. Additionally, some tuber plants (cassava, sweet potatoes) and legumes are cultivated. Traditionally cattle keeping is very important and still plays a major role in the economic and socio-cultural life of the local communities.

During the last decades the pressure on the natural resources has increased. This is partly due to a rapid growth of the local population and a high immigration rate of

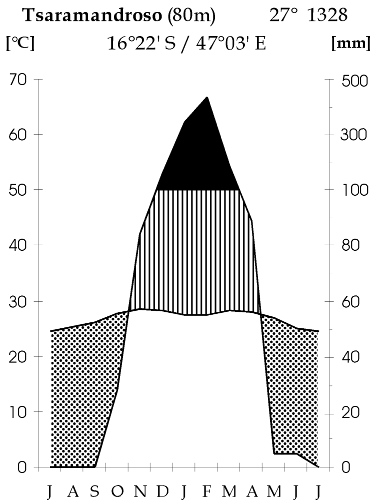

Fig. 1. Climate diagram according to Gaussen for the Ankarafantsika area.

people of heterogeneous origins. Families of Sakalava, Betsileo, Betsimisaraka, Sihanaka and other groups settled in the Ankarafantsika area (Anon. 1994). All four major valleys in the area now host many human settlements and the forest has been cleared by 'slash and burn' practices. Amongst the immigrants and the local population (mainly Sakalava) a long-term perspective on natural resource management is missing. This negative attitude was extended because of the loss of traditional land ownership and management practices. With no formal tenure, communities in and around the area have little incentive to invest in long-term conservation. The resources of the region are essentially in a state of unprotected 'open access' management. The short-term thinking is also reflected in the current, more or less chaotic, fire regime which only aggravates the ongoing ecosystem degradation. In addition, tree cutting – mainly for the needs of construction wood and charcoal for the town of Mahajanga – accelerates forest destruction. The reduced vegetation cover of the upper slopes favours soil erosion. On lower parts of the slopes and in valleys the sediments may act in part as fertilizer, but they also bury existing rice paddies. This ecosystem degradation endangers both the biodiversity and a sound socio-economic development of the local population.

In 1994, Conservation International started a new project for the conservation and development of Ankarafantsika with the aim to transform the already protected areas of Ankarafantsika into a National Park. The future Park will be ca. 140 000 ha in size; it will enclose the 'Réserve Naturelle Intégrale d'Ankarafantsika' and its buffer zone (established by decree in 1927) as well as the adjacent forest reserve (established by decree in 1929). The intention is to prevent any human use of the 'Réserve Naturelle Intégrale' and to integrally protect nature. On the other hand, in the forest reserve multiple use is permitted, although agriculture and human habitation are prohibited. For the new National Park it is foreseen that the local communities may directly use several areas, which will serve as a buffer zone, this according to contracts negotiated between the people and the Park.

The Project's main objectives (Anon. 1994) are to:

- ensure the conservation of biodiversity and wise use of natural resources in the Reserve and its buffer areas;
- ensure the stability of rice production in areas downstream from the Reserve that currently suffer from declining conditions of watersheds in the Reserve;
- improve the livelihood of people depending on the Reserve's resources – fresh water, grazing lands, firewood and charcoal, tubers, medicinal plants and other forest products.

Clearly, the achievement of these objectives demands substantial participation of the local community in both the decision making and implementation of the Project.

The Project team has identified the actual fire regime as the main factor endangering the objectives of conservation and sound development of the region of Ankarafantsika. On the other hand, fire can be an appropriate management tool in savanna landscape, if used properly.

In 1997, two missions for Conservation International were carried out in order to elaborate a fire management plan for the Ankarafantsika Reserve complex and the surrounding area. The plan is based on both actual knowledge about fire ecology and the socio-economic needs of the local population. Here, the fire issue will be outlined as part of the project's overall strategy.

The importance of fire at Ankarafantsika

Fire is undoubtedly one of the unifying characteristics of savannas and it is more frequent than in any other biome (e.g. Huntley & Walker 1982). Fires are either natural or man-made. Natural fires are mostly caused by lightning and must have occurred since the earliest appearance of vegetation in Madagascar. Actually, more than 95 % of all fires in western Madagascar are supposed to be man-induced. Anyway, fire has largely formed the landscape of Ankarafantsika.

Former and actual fire regime

Mankind learned to handle fire as part of land use, but also used fire for socio-cultural reasons. In view of introducing and developing modern fire management it is important to understand the development of the use of fire and the underlying perception by the population. The frequency, season, and intensity at which fires occur in a given region make up the 'fire regime' (van Wilgen et al. 1990). According to an old resident, there has been a common fire management for the vast rangeland of Beronono. The use and control of fire was governed by social rules (*dina*), for instance for rangeland management the season and frequency (every 2 - 3 yr) of burning was defined for each pasture.

Nowadays, large destructive forest fires occur frequently in the area of Ankarafantsika. The severe disturbance of the traditional land-use system also caused the disappearance of a common fire regime controlled by the local communities. The present situation is also reflected in the difficulty of mobilizing the population to extinguish fires. In addition, the prohibition of almost any use of fire by the colonial authorities and later on by the independent Malagasy government, much to the dislike of the local population, has most probably favoured a chaotic use of fire. Only recently a discussion started between environmental agencies (governmental and private) on a more flexible but controlled use of fire respecting the characteristics of the vegetation and the defined management objectives. An improvement of the situation requires that the new legislation under way, specifically defining the use of fire, will be approved.

Man-made fires

Deliberate bush fires serve many functions in the area of Ankarafantsika. Seven forms are listed below – not in order of importance. Particularly the first three types of fire have become a tradition in the Malagasy society. The list is not exhaustive; for instance a fire type called 'Donaka' is applied in order to facilitate detecting and catching of wild zebus. Furthermore, to light a fire may just become a habit without any exact reason. Also burning for pleasure only (pyromania) may happen.

Pasture burning

This type of grass burning serves the renewal and maintenance of the grazing land by burning the old tussocks (and other material not consumed during the wet season); it also prevents bush encroachment. For this purpose the fire is usually lighted on the Ankarafantsika plateau at the end of the dry season (see section on Fire characteristics). Although early dry season fires for promoting new shoots of grasses are very common in pasture management on savanna land elsewhere, this type of fire occurs very seldom on the Ankarafantsika plateau. This may be due to the lack of permanent water sources on the plateau during the dry season, which makes grazing difficult. Therefore, during the dry season, cattle are grazing in the rice fields (after the harvest) and the surrounding areas in the plain.

Slash and burn agriculture

This activity concerns the clearing of natural forests along the valley bottoms to gain land for agriculture; it is mainly practised by immigrants.

Clearing land for cultivation

The burning of residuals of the last harvest or of fallow land at the end of the dry season facilitates the preparation of fields for crop production. The risk of loosing control over the fire is low, if the local community assures control as was traditionally the case.

Charcoal production

The production of charcoal is widespread in the forest of Ankarafantsika and is often realised without a permit. The charcoal burners belong to the very poor and they sometimes do not know the appropriate technique. The burning of a charcoal pile is usually not surveyed permanently and therefore there is a high risk that the fire spreads to the surrounding dry forest.

Harvesting of Dioscorea spp. (yam)

32 different species of *Dioscorea* grow in the forest formations of Madagascar. Of these 26 species are endemic (Koechlin et al. 1974), of which none are cultivated. Some of the wild forms of yam are much appreciated by the local population, especially *Dioscorea massiba* and to a lesser degree *Dioscorea antaly*. For the harvesting of the tubers the population uses fire to facilitate the detection of the over-ground parts of these climbers. This uncontrolled burning may devastate large areas of dry forest.

Harvest of honey

Although people use fire for harvesting honey it seems that this activity is seldom the cause of forest fires in the Ankarafantsika area.

Fire as a political protest

Frequently people manifest their disagreement towards the authorities by setting fire. Most probably, the fire in the newly installed cashew-nut plantations (FaMaMa Project, Mevadoany) was such a case. The local population did not accept the loss of common rangeland to the Project.

Fire characteristics

The impact of fire on the flora, fauna and habitat of the ecosystem is very complex. Here, only the impact of fire on the vegetation component is discussed. This impact depends on the fire regime and the physiological adaptation of the vegetation.

Frequency

If grass fires occur infrequently they are far more intense than if they take place annually, due to the larger amount of available biomass. Repeated burning favours in general fast growing species. Forest fires behave differently with respect to the structure of the forest.

Season

Different types of fire may be distinguished according to their seasonal appearance. Natural fires caused by lightning may occur at the end of the dry season together with the first thunderstorms. Man-made fires may occur at any time during the dry season, but fires during the rainy season, after several days without rainfall may also be possible. Usually, a distinction is made between early and late dry season fires. Their characteristics and general impact on the vegetation are quite different.

Main characteristics of an early dry season fire

- Of rather low temperature and low intensity, due to the fact that part of the energy released is used to evaporate the remaining humidity of the vegetation and, to a lesser degree, of the soil (smoky fire);
- Less destructive to woody plants (the grass fire stops at the forest boundary line); may promote bush encroachment;
- Enhancing the dryness of the habitat and favours xeric species;
- When frequent, contributing to a shift of the forest boundary line at the expense of the grass savanna;
- Incomplete (heterogeneous) burning of the grass layer, mostly yielding patches;
- With a rather slowly advancing fire front;
- Reducing the protective vegetation cover, exposing the soil to a greater wind erosion during the dry season;
- Promoting new grass shoots during the dry season – assuming that the moisture content of the soil is high enough;
- Leading to some soil protection at the beginning of the rainy season (often with heavy rains) due to some remaining vegetation cover;
- Prescribed burning easy to control.

Main characteristics of a late dry season fire

- With high temperature and intensity due to the dry organic material;
- More destructive to woody plants;
- When frequent, contributing to a shift of the forest boundary line at the expense of the dry forest;
- Usually complete (homogeneous) burning;
- Rather rapidly advancing fire front;
- Resulting in bare soil at the beginning of the rainy season with increased risk of erosion by heavy rainfall;
- Difficult to control.

Main characteristics of a 'no burning' protocol

- Disadvantageous for caespitose species - plants no longer compete for space horizontally, but vertically; suffrutescent plants will become dominant, among them many legumes (Gillon 1983);
- Promoting woody plants and tall grasses (at the expense of short grasses) and species less resistant to burning at the expense of fire-adapted life forms; promoting bush encroachment (Menaut 1977);
- Increasing fuel loads and fire hazards.

Intensity

Temperature and duration determine fire intensity. The rise in temperature of grass fires during the advance of the burning front does not last for more than 4 -5 min. while the highest temperatures do not persist for more than a few seconds (Gillon 1983). In savannas the speed of fire spreading varies considerably depending mainly on (1) density of biomass, (2) type of fuel and (3) wind velocity and land relief. In secondary savanna at the Ivory Coast mean speed is ca. 500 m/h (Gillon 1983). Similar values are assumed for the Ankarafantsika savanna. Forest fires are hotter and advance more slowly – in closed-canopy dry forest at Ankarafantsika a few m/h (ground fires).

Fire temperature has been measured in experimental plots in the dominating grass-savanna type with *Aristida barbicollis* (cover of trees < 5 %; grass cover 60 - 70 %; height 160 cm) during the late burning of November 8th, 1997. 53 mm of rain fell on October 28th. During the fire, wind velocity changed from 0 to 2 (3) Beaufort and wind direction was constantly changing. At the measuring points head-fires were prevailing. Temperatures varied considerably from place to place mainly as a function of the variable biomass density and to a lesser degree due to changing wind conditions during the burning. Mean temperature at the soil surface was 380 °C (Table 1); the temperature during the burning process increased slightly from the surface to the 50 cm level; it was 430 °C where the grass layer (with *Aristida barbicollis*) was very dense. At 100 cm above the surface the temperature was only ca. 250 °C.

In scattered tree savannas (tree cover ca. 20 %) at Kagera, NW Tanzania, similar fire studies were carried out (Bloesch 1997 unpubl.). These savannas are drier, with only 800 - 900 mm/yr of rain concentrated in two rainy seasons, the height, cover and biomass of the grass layer was almost the same as in Ankarafantskika. The temperatures measured in the Kagera savannas are only slightly lower than those at Ankarafantsika. The main difference is that the highest temperatures are reached just a few cm above the soil surface. This might be explained by the high percentage of stoloniferous grasses (*Cynodon dactylon*, *Chloris gayana*) forming a dense grass layer close to the surface.

Early burning produces generally lower temperatures than late burning, which was confirmed in measurements in the Kagera savannas. Near-surface temperatures in early burning were somewhat reduced, but temperatures at 50 and 100 cm were greatly reduced, by about 48 % and 59 %, respectively. These results show the less destructive impact of early burning on woody plants.

The intensity of fire depends in general on the following factors:

- Amount and type of fuel (influenced in particular by the rainfall, past fires and grazing intensity);
- Moisture content of the organic material depending on the season and the daytime (e.g. higher dew content in the early morning and in the late afternoon at the beginning of the dry season);
- Prevailing climatic conditions (air temperature, relative humidity and in particular wind velocity and direction) depend on daytime; head fires advance much faster than back fires and therefore the duration of the thermal effect of the blaze is shorter but in general of higher temperature;
- Relief: the slope is very important for the speed of a fire: uphill burning is much more intense and therefore more destructive to the vegetation than downhill burning; the direction of the wind may increase or decrease the slope effect; the destructive uphill burning effect may be an important factor for promoting grassland on slopes.

Phenological stage

The ecological impact of a fire depends largely on the actual phenological stage of the vegetation. During the dry season most of the trees are loosing their leaves. At the end of September, about two months before the start of the rainy season foliation begins and the trees become particularly susceptible towards burning (late dry season fire). The beginning of foliation in the second half of the dry season is also a characteristic feature of the dry miombo forest in East and South Africa (Ernst 1971). In general, during the growth period fires are very destructive. The later the burning occurs in the wet season the greater is the reduction in the subsequent annual biomass production (Smith 1960).

Protection measures

The impact of fire on plant species depends on their reproductive strategy (seeds, sprouts, sucker) in general, and on their protective meristeme layer (e.g. kind of bark) and, particularly, on the location of the buds. Buds buried in the soil or protected by the bases of tillers and leaf sheaths are fire-resistant and buried seeds can withstand a temporary and moderate rise in temperature. Basal buds are well protected at the base of the tussocks, where temperatures seldom reach a lethal level during the fire (52 - 56 °C according to Adam & Jaeger 1976).

Table 1. Fire temperatures (°C). n.d. = not determined.

Height above soil (cm)	Kagera savannas, Tanzania Early burning	Kagera savannas, Tanzania Late burning	Ankarafantsika Late burning
0	n.d.	350	380
10	350	390	395
50	165	320	430
100	90	220	250

Certain life forms predominate in fire-maintained communities such as annuals (therophytes), hemicryptophytes and geophytes among perennial herbaceous plants (Gillon 1983).

Impact of fire on the dynamics of savanna landscape

For a better understanding of the impact of fire on the ecosystems it is necessary to recall some general principles of the dynamics of a savanna landscape. Nowadays, savanna formations occupy ca. 80 % of the western region of Madagascar and the forest survives in isolated patches (Koechlin 1993). The prevalence of savanna formations justifies the use of the term savanna landscape. The dynamics of the savanna landscape is still poorly understood. The structure of the different vegetation formations varies considerably in space and time mainly in function of the interactive factors climate (essentially rainfall), plant-available nutrients and soil moisture (soil type), herbivory and fire. The classical equilibrium view of savanna dynamics (Walker & Noy-Meir 1982) has been replaced by a disequilibrium view that suggests that the coexistence of trees and grasses is achieved through disturbance (Skarpe 1992; Scholes & Walker 1993). Under present climatic and soil conditions the actual distribution pattern of dry forests and savanna formations in the western part of Madagascar, represents an artificial balance maintained by human activities and high frequency of fire (Koechlin 1993).

The transformation of primary forest into secondary vegetation is mainly influenced by human activities and in particular intentional burning. About 2000 yr ago, Paleo-Indonesians were the first immigrants to the island and practised slash and burn agriculture and pastoralism in which fire was a necessary tool for clearing land and maintaining secondary grassland vegetation (Battistini & Verin 1972). Ever since, the frequency of fire steadily increased and has contributed to the destruction of the primary forest. The lapse of time since frequent fires started was too short to select woody species adapted to burning. It is still an open question whether other people lived in Madagascar previous to the Paleo-Indonesians and how they used fire.

An important feature of the savanna ecosystem is its resilience to changes induced by one factor becoming temporally dominating. However, the resilience potential between the ecosystems of the Central Plateau and those of western Madagascar is very different. Mountain forests in the tropics are much more sensible to disturbances than dry forests, and are especially susceptible to fire. In dry forests, natural fires are a very common event, contrary to the mountain forests where natural fires are very rare. The transformation from the original mountain forest into grassland on the Central Plateau is almost irreversible. The development of secondary forest is hindered by low soil fertility (enhanced by the effect of erosion due to the destruction of the forest cover) and by the absence of dynamic elements in the forest flora able to compete with the dominant species of the grassland. Contrary to the current grassland formations of the Central Plateau the resilience potential of the western savanna landscape is quite high – which offers more management possibilities. Several examples exist in the Reserve which support this statement. The best example is the former village of Ampijoroa, abandoned ca. 30 yr ago (see Fig. 2). The former location of the village is hardly visible in the young dry forest. Only a few remaining teak trees of a former plantation within the village provide evidence of the earlier habitation.

Many observations support the idea that the dry forest represents the local climax vegetation (Koechlin 1993). The remarkably low species diversity and the homogeneity of the flora, even throughout diverse habitats, confirm that the savanna is a secondary vegetation. Of the 300 plant species occurring in the savanna, only 85 are true savanna species, and among these only 18 are endemic to Madagascar. Furthermore, the fauna of the herbaceous formations is very poor and includes almost no indigenous species, which adds further support to the viewpoint that these areas were formerly forested (Koechlin 1993). This fact supports the thesis that the savanna formations, except those which have an edaphic origin, are fire-climax savannas of recent genesis.

Numerous wild fires occur in the Ankarafantsika area; in particular large-scale bush fires happen frequently in the northwestern part of the Reserve. The variation in frequency, season and intensity of fires lead to a patchy landscape. Usually, fires start in the grass savanna. The relatively high seasonal rainfall and the low grazing intensity by cattle (large indigenous mammals do not occur) within the Reserve permits the production of large amounts of dry grass. The burning process is very different between dry forests and grass savannas.

Dry forest

Plants of forest and thicket formations are very susceptible to fire damage, the trees and shrubs being generally thin-barked and with moderate or poor regeneration potential after damage (Langdale-Brown et al. 1964). At the beginning of the dry season dry forests usually do not burn and savanna fires stop at the forest boundary line. Later on in the dry season, the dry and continuous litter cover allows forest fires which may be very destructive to the forest. However, the frequency of fire is a very important feature in the assessment of the impact of fire (Rabemazava pers. comm.). If a first fire occurs in a mature dry forest (closed canopy of old trees) usually only the ground cover composed of litter will burn. A first passage of fire may mostly damage shrubs and small trees, which may decay later on. If a second fire happens in the next one to three years the larger dead biomass resulting from the woody plants killed during the first fire, may result in a more destructive fire which will damage the dominating trees and open the canopy. The higher light intensity on the ground may allow growth of grasses. It is supposed that three to four fires within a period of ca. 15 yr may transform a formerly intact dry forest into savanna. Forests on red sand tend to transform into a grass-savanna mainly dominated by *Aristida barbicollis*; forests on white sandy soil tend to become a shrub savanna without *Aristida*. Destroyed forests with an open canopy may recover again by natural regeneration if protected from fire.

Fig. 2. Young dry forest of an area inhabited in the past. Note the teak trees reminiscent of the former village of Ampijoroa, abandoned 30 yr ago.

Grass savanna

Regular burning and in some areas overgrazing induce a progressive degradation of the grass-savanna dominated by *Hyparrhenia rufa* to a savanna type with

Heteropogon contortus and finally into a type with *Aristida barbicollis*. This final stage cannot effectively protect the soil against erosion. This dramatic change in plant composition considerably decreases the fodder value (in Tropical Livestock Unit/ha) (Anon. 1996):

Grass savanna type with *Hyparrhenia rufa*:	2.46
Grass savanna type with *Heteropogon contortus*:	0.60
Grass savanna type with *Aristida barbicollis*:	0.30

Fire management plan

As outlined before, uncontrolled fire may have severe consequences for the biodiversity and the livelihood of the local population. The fire management plan should contribute to a better use of fire in the Ankarafantsika area thereby helping to achieve the Project objectives (see Introduction).

In the long run the local population should take full responsibility for the management of the local resources in the buffer zones and on community land, using fire properly (Tachez 1995). Therefore the approach will be community based. In the following the different principles of the strategy will be discussed.

General principles

- Support the gradual transfer of responsibilities for resource management to the local communities in the buffer zones; close collaboration with the agencies involved in this nation-wide process called GELOSE (Gestion locale sécurisée).
- Improve the mutual trust between the primary resource users (farmers, herdsmen, fishermen, loggers and others) and the Project agents (prerequisite for any sound collaboration).
- Revitalize former fire regime as far as it existed (focusing on rangeland management); such might be an ideal start for establishing, together with the local population, a fire management plan; obviously, the old rules (dina) for fire use have to be adapted to the actual socio-economic situation.
- Define the roles of the different participants in Ankarafantsika; the duty of Conservation International will be to coordinate the activities and to build bridges between the partners participating in the resource management.
- Integrate the fire issue as part of the overall operation of the Project (integrated approach).
- Use of force by local authorities as a way out (rather ineffective in the past!).
- Develop a fire management strategy in view of the goals of the Project. This strategy has to be flexible.
- Define first-priority intervention zones.
- Interlink the Project operation with research activities: research data from the experimental plots and the socio-economic studies will be integrated in the ongoing operation; likewise new problems observed during the implementation of the Project will be considered in the research program (i.e. on farm research).

Technical principles

The fire management will use a fixed burning protocol defining the deliberate application of fire considering the specific features of the vegetation and the defined objectives. First, a controlled early burning will be applied for pasture management. This type of burning will allow a better protection of the dry forest, reduce the risk of erosion at the beginning of the rainy season and may also meet the interests of the cattle keeper.

The specific fire regime will be defined as follows:

- Early burning: the burning will be applied in some clearly defined areas two to three weeks after the last rainfall. This type of burning promotes the development of new grass shoots during the dry season which are biologically younger than mature grass and therefore are of a higher fodder value – higher protein and mineral content (Gillon 1983) and lower content of indigestible material such as cellulose and lignin. Furthermore, early burning is easy to control by the people and does not enter the dry forest. The burnt grassland along the forest boundary line may serve as a firebreak against destructive fires coming from the adjacent grassland at the end of the dry season.
- Spatial definition of the burning according to the state of the pasture (considering a controlled intensity of grazing and rotational grazing).
- Frequency of burning for the same pasture: every two - four years.
- Firebreaks (if possible established by controlled burning at the very beginning of the dry season) will only be used for the protection of special sites (e.g. the Botanical Garden).
- Controlled harvesting of *Dioscorea massiba* and *Dioscorea antaly* within the Reserve on permanent sites without using fire.

A first annual action plan has been elaborated considering these principles. The subsequent action plan will be based on the experiences and the results of the first period.

Outlook

In most African countries almost any use of fire is still prohibited by law. Only recently a new attitude towards the use of fire acknowledges controlled fires as a sound management tool, if used properly.

Considerable experience is already available in fire management programmes led by organisations for protected areas or large rangelands worldwide. However, only few cases are reported where the local population will be in charge of the fire management programme for land use.

The success of a sustainable management in the area of Ankarafantsika will depend on the following points:

- Transfer of responsibilities for resource management to the regional and local level requiring an efficient political restructuring; local and regional leaders will have to take greater responsibilities traditionally reserved for the central government. This decentralization will require a long transition period.
- The new land tenure system which is under way, should help the resource users to gain access to land tenure, which is a major incentive for investing in long-term conservation; land ownership taxes should not render (formal) land tenure unattractive.
- Approval of the new legislation under way, specifically defining the use of fire.
- Local population's awareness and substantial participation of a community involved in resource management (GELOSE) as to the new National Park rules.
- Identification of attractive economic advantages for the resource stakeholders who support the sustainable use of local natural resources.
- Ability of Conservation International to solve conflicts of interests among the different partners participating in the management of natural resources (in particular between residents and immigrants).
- Long term engagement of the implementing partners and their staff.

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