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SUMMARY

The forest ecosystem is essential in its role of securing the smooth development of natural processes and in buffering a number of natural phenomena affecting the various habitats on earth. It hence plays a number of protective and environmental functions that are important for the maintenance of life forms and the well-being of man. Human kind has always taken these roles as granted and in most of cases attention to, and awareness of, these functions have remained relatively low as long as they have not been impaired by deforestation, change in forest cover and especially fragmentation of the forest mantle. Today a number of threats to forests contribute to affecting the plain expression of the protective functions of the forest. Climate change may affect the capacity of forests and trees to buffer soil erosion and land degradation. This document focuses on three major areas to highlight and characterize the protective functions of forests; they are the role of forest in protecting against the tellurian degradation and loss of soil and fertile land; the forest and its role of protecting the biological diversity in delicate and fragile ecosystems in mangrove and other coastal areas; the forest as a tool for combating land degradation. The recently signed UNCED and post-UNCED Conventions have accorded serious attention to the contribution of forests in mitigating peaks and lows of climatic factors, in maintaining the biological diversity and to its role and place in the conservation of the land resources as a whole.

Keywords: Forest, protection, benefits and services, mountain forests, coastal forests, dry forests.

1. INTRODUCTION

The forest, as a natural buffer, plays an important role in maintaining the ecological balance while being at the same time a key element in the landscape and a supplier of raw material and various protective services to societies. An essential goal of forest policies must be to maintain the existing forest area and endeavour to expand it in areas of low forest cover whenever possible (in particular in fragile ecosystems such as mountain and dry areas) as suggested in Agenda 21. Society must be kept aware of the multiple functions of forest in the utilization of its basic products and in the many protective, recreational and landscape structuring functions. New trends in forest management take more and more account of these diversified functions. According to the relative weighting of these functions, forest management and silvicultural practices may change drastically, as well as the policy options orienting the main objectives and goals of forestry. The economic functions of the forest resources remain still very important as national and world economy need raw timber occurring from

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forests; however, sustainable forest management has to conciliate these many functions. They guarantee the equitable satisfaction of potentially diverging needs and aspirations. A number of old and post Rio conventions have promoted approaches and policies geared to supporting conservation and sustainable management of natural resources; they have, together with the Agenda 21 provided a framework through which the forests of all types may be safeguarded and the protective functions and services they deliver strengthened.

This document will look at how the overall situation of forest resources is affecting their capacity to deliver the protective functions they are usually expected to provide, what are the trends in the understanding of these protective functions, how initiatives taken and activities developed are linked with these functions and how the implementation of UNCED agenda 21 and related conventions help safeguard the protective functions of forests. This review will be done with special reference to a selected set of ecosystems relatively fragile and to which the XI World Forestry Congress decided to give special attention, namely the mountain ecosystems and watershed management, the dry forest and tree ecosystems and the coastal forests and wetlands.

2. GENERAL CONSIDERATIONS ON THE PROTECTIVE AND ENVIRONMENTAL ROLE OF FORESTS

The forest can deliver any of the functions of protection or conservation expected from it, only if it is either in its natural state and under good natural ecological conditions or when in use, it is managed in a sustainable manner. Under such conditions, health and vitality are very important. The efforts towards sustainable management of forests have included these two fundamentally important characteristics among the most significant criteria of sustainable forest management. It is the vitality of forests that allows them to grow with sufficient strength and vigour in a way to counter physical forces affecting soils through water erosion. It is this same vigour that allows a well structured architecture and rich foliage that can counter wind erosion.

Health of forests is fundamental to many environmental functions of the forests. However, forests are often affected by insects and other pests. They may be affected by a number of physiological alterations depending on climate changes, especially droughts. Droughts of the 1970s in Africa have for instance significantly affected the health and vitality of forest and tree formations in the dry to dry sub-humid regions of the continent; the degradation processes that have been triggered have led to a progressively aggravated decline and desertification. In Europe the decline of forests, that has been profusely described in the early 1980s and that revealed to be serious concerns, has strongly affected their environmental and especially recreational functions in some areas.

Vitality is an important notion and a concept that has been introduced in the criteria for sustainable forest management. The vitality is a result of a general good physiological functioning of the organism: a tree having good vitality makes vigorous growth or produces strong shoots; flowering is massive and fruiting is abundant; the faculty of vegetative regeneration is strongly present and permits reasonable perpetuation of the interested formations and hence the normal functioning of the various protective roles of the forest.

With health, vitality and proper state of conservation, management and development secured, the forest intervenes especially in the following major environmental and protective functions.

- *Protection of water resources*: through its foliage, the craggy bark, and the abundant litter, trees and forests decrease the speed of water dispersion and favour slow but total infiltration of rain water; it is also to be noted the capacity of trees especially in dry areas to retain other precipitations such as mist that then can be collected and stored for use. The combination of these elements makes it possible that in apparently very arid environments an important amount of water is

stored in the ground which can support the survival of trees and forests in often adverse conditions. Reducing the erosion, the forests also provide cleaning processes of natural water.

- *Soil Protection:* The forest canopy slows down the wind while its dense network of roots holds the soil in place; added to the buffering function of water flow as mentioned above, these characteristics protect against wind and water erosion, land movement (mass slides and falling rocks) and, under cold climates the risks of avalanches; with the combination of slower dispersion of water and its forcing down to phreatic and intermediary watertables, the forest exerts an important buffering effect that protect against flooding or severe river bank erosion; this latter function is fundamentally important. Many of these functions may, however, be impaired by inadequate or unsuitable management practices that allow inadvertent barring of forest soils or the existence of empty space in stands. This degradation, if unchecked, leads to deforestation which in turn leads to exacerbated run-off, leaching, destruction of soil structures, growing erosion and eventually desertification.
- *Buffering local climate and reduction of gas emission impacts:* Through the control of wind velocity and air flows, the forest influences local air circulation and may thus retain solid suspensions and gaseous elements; it can filter air masses and retain contaminants. The forest exerts a definite protective effect on neighbouring human settlements and especially crops. This capacity is used in the protection of inhabited areas especially when adjoining industrial areas and generally in urban forestry.
- *Conservation of the natural habitat and biological diversity:* The forest offers habitat to flora and fauna and, depending on its health, vitality and ultimately the way it is managed or protected, secures its own perpetuation through the functioning of the forest ecological processes; under natural circumstances the many successions of states evolve gradually towards an equilibrium, the climatic formations and associations that should be the optimum state depending on the climate and physiographic characteristics. In Europe, almost half of the ferns and flowering plants grow in the forest. Due to its size and its structural diversity, more animal species are found in the forest than in any other ecosystem. The capacity of forest to provide a suitable habitat to its various components also strongly depends on the composition, density and structure. Composition and structure strongly influence diversity while density may enhance protection. It is admitted that mixed species forests offer better habitat to wildlife than pure stands. This should be kept in mind when considering plantations or the management and silviculture of deeply modified forest ecosystems.
- *Recreational and other social functions of the forests:* Apart from these direct physical and biological protective functions, the forests in general have gained increasingly important recreational functions during the last five decades. In the vicinity of cities, tourism and health resorts have flourished benefiting from the forest environment; in forested areas of developed and developing countries alike, secondary residences are getting man back closer to the forests. The management of forest stands in these areas should then be more and more oriented towards objectives relating to the well-being of people, leisure and recreational services, protection of man from the effects of urban concentrations and industrialization. To better meet these needs, silviculture and forest management options should then be adopted by promoting attractive stands of various species and diversified structure. The forest should be provided with the adequate equipment, access and road network to build conviviality and reduce fire risks.
- *Protecting the forests to protect from cultural erosion:* While urban communities are striving to be closer to nature, at the same time evolution of the world and local forest economies may threaten other protective functions of natural forests in the developing world where forests have still maintained their cultural and religious functions. It is a challenge to the forestry of the 21st

century to also cater for these needs and maintain the cultural dimension of the protective functions of the forests. The efforts to save tropical humid forests, special plant formations presently threatened, boreal forests and some remaining old growth in the temperate world should be made not only to protect and conserve biological diversity that these formations hold in plenty, but also to safeguard livelihoods and cultures attached to these ecosystems. A number of innovative management options and many social and community forestry initiatives have addressed these needs, along with maintaining sustainable livelihoods including the trials to extractive reserves in the Amazon and the new partnerships and alliances being developed in countries as diverse as Mexico, Mali, etc.

3. PROTECTIVE AND ENVIRONMENTAL FUNCTIONS OF FORESTS IN SELECTED FRAGILE ENVIRONMENTS

3.1 Mountain forests and sustainable mountain development

Mountain ecosystems are among the fragile ecosystems targeted by UNCED Agenda 21; they are dealt with in chapter 13, "Sustainable Mountain development". The many activities developed intensively during the last five years since Rio have heightened awareness of the many functions of mountains; they are a repository of rare and rich plant and animal biological diversity. They contain unique gene resources underpinning agriculture and animal husbandry in the particular circumstances and farming systems prevailing in high valleys and plateaux. They provide steady flow of invaluable water resources with the related renewable energy potential. They are hosts to, and protectors of, a diversity of human races and cultures. The role of forests in conserving these resources and the services linked to them is tremendous.

In high mountains the forests protect settlements and communication systems against avalanches, falling rocks and landslides. In the European Alps, parts of the protection forests have been submitted to long-established management practices that have tended to maintain a correct mix of evergreen and leafed species. But trends are strongly pushing towards unsatisfactory changes. Mixed stands are giving way to monospecific forests and many protection forests have been weakened and have become over-aged. They grow more and more sparsely. In many cases the presence of game prevents natural regeneration through browsing and increases the degradation of the forest ecosystem and reduces its protective capacity. Measures to counter this negative trend or to restore the forest ecosystem includes among others biological measures such as reforestation, engineering work and active silvicultural practices that promote and assist natural regeneration. Also, excessive game population must be reduced and at the same time observation of the natural regeneration, when it is happening and growing will help assess the adequate stocking level.

In other parts of the world the same decline may be observed but most of the degradation occurs as the result of the permanent fight of rural poor especially in these marginal areas to eke out for their living. In North Africa, in the African plateaux, in the Andes and in the Himalayas, the search for fuelwood, the grazing of animal especially the well-adapted, ever-coping goats and marginal agriculture have been mentioned as among the major factors of mountain forest fragmentation, degradation and loss. Mining in many parts of the world have been also mentioned for disrupting mountain ecology and especially the degradation or destruction of unique biological diversity, in some cases affecting endemic species and the processes in which they are involved. Illegal mining in watershed areas, as signals E. Hernandez may also often be the sources of contamination of major water-courses.

Many fights of ecological groups have highlighted the possible negative influences of communication lines and roads as their establishment entails the deforestation of large stretches

which affects the habitat of species of high biological significance. However the most potent root causes are, as highlighted by Hernández (1997)³ in Latin America, i) the state of inherent fragility of young mountains; ii) the extreme poverty of the population and the loss of stamina and resolve in face of drastically poor and yet rapidly degrading social conditions, iii) the segmented approach to development and lack of institutional cohesion and coherence and lack of suitable and participatory extension.

Protective functions of mountain forests and climate change require special attention. This subject has been largely studied world-wide. Göttle reports on the possible consequences of climate change in the way mountain forests in Europe may then deliver the buffering functions they have (results of research of the Bavarian State Office for Water management):

- Higher temperatures will lead to the rise of snow and ice line with more favourable conditions to vegetation, but with higher “erodibility”, the shifting of permafrost line creating more instability in the areas yet to be colonized by vegetation and provided with more stable soil conditions later.
- Frequent changes between thawing and freezing will release more weathering material and increase related risks of rock fall and landslides while making the consolidation of vegetation more difficult;
- More water precipitation with the predominance of rains will lead to water saturated soils which will eventually reduce shear resistance and loss of stability, conditions unfavourable to the establishment of vegetation; this means then, more earth and debris flows. More surface run-off may also occur throughout the year leading to more erosion.

Mutatis mutandis similar changes in intensity but not in directions of change may be experienced in mountain areas more strongly than on plains, meaning more spectacular changes in mountain forest ecosystems, due to the concentration on short horizontal distances of phenomena that otherwise happen in a differentiated manner and over greater distances on flat land.

Special attention to mountain forests for the future and greater efforts in watershed management: The Mountain Agenda which has been very active in the framework of chapter 13 and the creation of the world-wide Mountain Forum and its regional chapters, has stressed the need to balance the unidirectional flow of resources including forest resources and services from the mountain downwards. The need to find innovative funding mechanisms and fresh policy options that restore the overall balance between mountain economies and societies in lowland areas was strongly advocated. The efforts to conserve mountain forests in this case cannot be supported only by mountain communities.

Hernández sends the same message regarding tropical mountain forests; he stresses that interested societies are more and more aware of the importance of the cloud forests in the production of high-quality water in watershed of tropical mountains. Hence, a better comprehension of the needs of sustainable forest management *and* development must be shared throughout the watershed, if mountain forests and beyond, mountain natural systems and socio-economic systems are to be maintained prosperous for mountain and national communities, and also for regional solidarity. In this context many have called for more efforts for the management of watersheds that aim not only at physical restoration of benign processes in the flow of water resources and solid material, but which aim at sustainable development of mountain systems. This will be achieved through *inter alia*, i) the stabilization of livelihood systems, ii) the improvement of the living conditions in mountain areas, iii) the identification and promotion of innovative income-generating activities and alternative employment, iv) the restoration of equity and solidarity between upstream and lowland communities.

3.2 The forests in the conservation and sustainable development of drylands

Trees and forests in dry regions have truly multiple functions. They provide a number of services that tend to buffer the harsh conditions and processes prevailing in dry zones especially in tropical

areas. The environmental functions of trees and forests under dry conditions relate to a number of aspects including, among others, the well-being of humans and animals, the productivity of cropland, the overall protection of land and water resources and the conservation of biological diversity. Y. Berte (1997)⁴, through Malian examples and lessons of universal value, has identified the many roles of forestry in drylands highlighting prerequisites to, and results of well-guided forestry related activities in the rehabilitation of natural resources and especially desertification control. He mentions the importance of training and technical advice and extension for rural populations; the improvement of the knowledge base of resources; the need for promoting new technologies; the major involvement of interested people and the devolution of responsibilities to their organizations.

Under dry tropical conditions humans and animals alike are submitted to a set of climatic conditions that make life uneasy and uncomfortable. Extreme heats, sandstorms and hot winds are the most taxing factors that challenge comfort and livelihoods in dry areas. Populations have used the trees and forests to protect themselves from these elements and many adaptations have been put to use. Natural vegetation has been conserved in most of the new human settlements. In many open forest systems, from the humid dry forests to the steppe formations, large stretches of tree covered land have been left untouched and protected to protect living areas. As it has been often difficult to protect natural formations and make them sustainable around dwellings when these evolve towards big cities and agglomerations, efforts to plant urban trees and peri-urban forests have developed in many dry areas with vigour and continuity. In Sahelian countries, for instance, efforts to install peri-urban forests date back to the early 1970s and have kept growing around all Sahelian cities. In the Near East, as report Ingrid E. Schneider and W.G. Burnet (1997)⁵ talking about arid land forestry in Jordan, “socializing with one’s extended family by picnicking in the forests is integral to Arab culture and recreation and forests are the primary weekend destinations of Jordanians who have vehicles”. They add that “the few forests developed for recreation purposes are estimated to serve more than 100 000 visitors annually”. The same pattern can be observed in the Maghreb countries and throughout the Middle East to Iran where cities like Ispahan, Teheran and others have magnified the role of trees and shrubs in the protection of the immediate living environment of man and enlivened urban environment.

While it has been difficult to conserve and manage the natural environment and in particular the natural forests around cities due to pressures for fuel and habitation, modern city planning in these areas have provided for organized plantation of peri-urban forests. Excellent examples of this trend can be found in the Sahel and everywhere in North Africa and the Middle East. The development of urban forestry principles and practices will encourage this trend. In the inhabited areas tree planting has tended to maintain trees in the inhabited sections of village lands. A number of studies have shown that trees providing shade, although most of them are exotic species, are intensively used by populations albeit the criticism that may be lodged against them. Indeed, all these negative statements notwithstanding, a number of introduced trees in tropical dry areas continue being profusely used as they efficiently provide services buffering heat, protecting against sand storms and beautifying the landscape. Species such as the neem (*Azadirachta indica*) and the acacias recently introduced in the Sahel (many of them from Australia) have proven invaluable in implementing these essential functions in the dry regions.

In croplands, the agricultural patterns have developed the parkland system that not only was meant to continue maintaining fertility of croplands but also to protect men and animals. These types of formations prevail in all dry to sub-humid areas from the *campo* type formations of the Iberian Europe to the *Leguminosae* dominated parklands of sub-humid to dry West Africa and Southern Africa. Indeed, dry area tree species include an immense population of *Leguminosae* and other nitrogen fixing tree species. These play an irreplaceable role in maintaining soil fertility. This function is of tremendous importance in areas where populations with worsening economic conditions can less and

less afford chemical fertilisers. The selection of these multi-purpose nitrogen fixing species and their promotion are essential to safeguard land productivity in the interested regions. Trees left then have a number of purposes: providing complementary food items, maintaining soil fertility and also beautifying the landscape. The most documented example is the pan-African *Acacia (Faidherbia) albida* of dry and dry sub-humid areas of the region south of the Sahara; it provides shade and feed to animals and natural nutrients to crops. The parkland system referred to above contributes efficiently to the maintenance of these residual tree communities; however, a number of new and rapid socio-economic developments have entailed the cutting and use for fuel and posts of tree species that hitherto had never been used for such purpose. These social changes have modified the interface man/tree and efforts in social and community forestry have the challenges to counter and restore tree protection practices that tended to maintain the conservation of trees of particular importance to the communities in drylands. Modern agroforestry programmes must help better understand these systems and encourage their conservation, improvement and replication.

Deforestation induced by use of forest and tree resources has been aggravated by the degradation of climatic conditions in many areas of the world. The most affected countries are those recognized by the United Nations in Africa and to which priority has been given in the negotiation and the implementation of the UN Convention to Combat Desertification and Drought. Tree planting in areas threatened by desertification or the management of dry tree formations contribute to protecting the soils and restoring the productive capacity of the land. The most spectacular initiatives in desertification control are the activities to stabilize sand dunes. These have been implemented with remarkable success in West Africa (Mauritania, Niger and Senegal), in North Africa (Morocco; Algeria, with the huge initiative of the Green Belt that has shifted from massive plantations to an approach towards integrated rural development; Tunisia and Libya), in Asia (India, Iran and Pakistan among others). This is why the role of trees and forests to control desertification and mitigate the effects of drought has been fully recognized and promoted in all the programmes being implemented to control desertification.

Tree planting goes now more and more with associated techniques including water harvesting, bundling and terracing, establishment of micro-catchments and moon crescents to collect all possible water resources. A number of projects are working in this sector using a variety of approaches from heavy machinery to manual work and a variable degree of association of various options.

The National Action Programmes to implement the UN Convention to combat desertification will promote these actions in the larger national initiatives to combat land degradation, food insecurity and poverty. Although tree planting has been heralded as the first and foremost tool for desertification control, many social, economic and ecological considerations have re-evaluated its role and position. The NAP processes have recognized this and involve a larger set of integrated activities. However, seen as a potent multi-functional tool among others in land degradation control, tree, shrub and grass planting can constitute a powerful complex when implementing water conservation and erosion control measures, rehabilitation of exhausted croplands, diversification of village landscape to include trees of various functions and services, stabilization and reclamation of lands. Forestry, agroforestry and urban tree planting will then remain very high in the agenda of National Action Programmes to combat desertification. It is certainly expected that this Congress and the satellite meeting on the role of forestry to combat desertification which has preceded it, will come up with ideas and recommendations for action that will consolidate the contribution of foresters to the effective implementation of the Convention.

The biological diversity of drylands is often overlooked. Yet the tree and forest systems and the grassland expanses in dry areas are important repository of biological diversity whose constituting species have developed ability to live in the harshest conditions of water deficit ecosystems. Drylands

have provided a number of species that contribute to many protective services and various materials. The provision of rangelands and food items such as the Tef in Ethiopia, the date palms, the various species of cactus and agave are only a few examples of the contribution of dry ecosystems to the protection of ecosystems, to feed and food supply.

Animal species of the dry Andes, the Sahara, the arid parts of the Sahel, the Asian and other deserts are of extraordinary beauty and utility to human kind and yet their habitats are being rapidly threatened as four-wheel drive vehicles may reach any corner of these lands and hunting of these marvellous species has always taunted sportsmen. Formations around oases are also evolving very rapidly as these ecosystems are apparently being exposed to harsher conditions. More animals, increasing human population around, produce heavier trampling of soils and overuse of water resources at the expense of natural plant associations and formations. An example of the impact of this type of negative evolution for animal and other natural resources is again given by Schneider and Burnett who exemplify the evolution of the critical habitat of wildlife in Jordan where forests and plants, before “frequently described as green and rich in wildlife”, contain now only scant remnants of the primeval formations. This has led to endangered wildlife species such as the Nubian ibex (*Capra ibex nubiana*), the Arabian gazelle (*Gazella gazella*) and the roe deer (*Capreolus capreolus*) now reintroduced. The same is true for areas before covered by acacia stands in the Arabian peninsula, in Syria, in North Africa where many programmes of steppe ecosystem rehabilitation and species reintroduction are being conducted.

The same concerns are nurtured for dryland ecosystem germplasm. Woody species of these ecosystems, especially from the genus *Acacia* and *Prosopis*, provided due precautions are taken, have a huge potential to support desertification control measures. Other plants of the dry systems have strong potential for drug potential; apparently innocuous plants may have in their systems extremely powerful substances at high level of concentration and effectiveness that research has still to discover and make use of in medicine and other chemical sectors (Timmerman, 1977)⁶. Local traditional medicine practitioners have this knowledge and use it for the well-being of their communities. The protection of the forest and tree ecosystems of these lands must be secured to eventually conserve these riches for present and future generations. The traditional knowledge and technologies developed locally should also be fully explored, rehabilitated and promoted.

3.3 Protection of forests in coastal systems and wetlands for their productive, protective and environmental functions

Coastal systems, wetlands and rivers have in common the special linkages with fresh, brackish or salt water resources. They benefit from the presence of water but may also suffer from it directly or indirectly. Forests generally benefit from the constant availability of water as allied formations have generally built adaptive physiological functions or biological variations that permit survival and development. However, as the status of the water bodies varies through droughts or excessive influx of new amounts from rains or other processes related to exceptional run-off, the systems may be negatively affected and their functions threatened. The fragility of wetland, coastal and riverine forests and other formations is linked to these phenomena.

Kabii, Choudhury, Zheng Songfa *et al.* and many other authors of submissions to the XI World Forestry Congress have largely documented the various aspects related to these ecosystems and the forests prospering in them, but the most important body of considerations relate to wetlands and especially to mangrove formations. As defined by the Ramsar “Convention on Wetlands of International Importance especially as Waterfowl Habitat” and as recalled by Kabii, wetlands are “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not

exceed six metres". Kabii includes in these areas a "wide range of wetland types including those under forest cover, such as mangrove forests, floodplain forests, peatland forests, bog forests, Melaleuca swamps and palm forests". A number of water and woody plant systems are well known throughout the world that exemplify the relationships of wetland and trees and the evolution of these relations; among them the French *Marais Poitevin*, the *Camargue*, the Mexican *Chinampas* and the huge *Pantanal* shared by a number of southern American States. Changes affecting forested wetlands may be due to infrastructure works including drainage, but also to natural phenomena induced by drought, or alterations in the water supply systems that feed the wetlands, introduced by human industry.

Due to their linkages with water and their intrinsic characteristics (continuous and steady supply of water, limited depth, usual influx of nutrients due to water inflows, etc.), wetlands are particularly rich ecosystems and their fragility may be also due to competing plans for their use. The wise use of these natural systems as delineated by the Convention includes i) the formulation and implementation of comprehensive national wetland policies to be integrated in the national planning processes; ii) the application of the Convention's criteria to identify and designate wetland sites of international importance for conservation; iii) the application of a number of other tools and mechanisms generated by the Convention (management planning guidelines, monitoring of the wetlands experiencing changes due to development initiatives, measures to obtain or provide specific assistance to solve problems encountered by the threatened sites mentioned above); and iv) in summary, contribution to the implementation of the eight-objective 1997-2002 Strategic Plan recently adopted by the Convention.⁷ Objective (vii) of these, calls for the mobilization of "international cooperation and financial assistance for wetland conservation and wise use in collaboration with other conventions and agencies, both governmental and non-governmental. This disposition is the gateway to conservation, management and sustainable development of wetland forests including mangrove forests.

In the international efforts to assess wetland forests, more efforts will be needed not only to approach the evaluation of all wetland related forests but also to better assess their biological diversity. The special efforts that FAO and the World Conservation Monitoring Centre intend to dedicate to protected areas in the next round of the world forest resources assessment will probably improve data on protected forests in wetlands.

Mangrove forests are among the most intensively and diversely used forests in the world. They provide land resources for agriculture especially the development of rice paddies; they are extremely rich fisheries; some of their fruits are directly consumed and they are in many countries the main sources of fuelwood supply for growing coastal cities. Mangrove formations have, for instance, paid a heavy tribute to the growth of a number of African Atlantic Coast cities not only for the wood energy, but also space for new dwellings. On the coast of the African Indian Ocean a number of changes in land use and even the browsing in mangrove formations by camels are taking the last remains of these mangrove formations. In Asia the state of mangrove forest conservation and management, including a wealth of legal and regulatory measures, were brilliantly documented by Choudhury (Bangladesh, Cambodia, Indonesia, Malaysia, the Philippines, Thailand, etc.) and Zheng Songfa *et al.* (China). The silviculture and management of mangrove forests have known many achievements and much progress. Many plantation initiatives have succeeded but a number of technical problems remain, depending on species biology, training of staff and a number of local conditions including pollution problems as recorded at this Congress by Zheng Songfa *et al.* (1997)⁸ Future efforts in mangrove conservation, management and development will include i) efforts for increasing management and silvicultural efforts in African mangroves including reforestation; ii) better knowledge of the resources especially, again, in Africa; iii) networking for further dissemination of technologies concerning mangrove forests given the huge gaps between countries, especially between Asian countries and the rest of the world; and iv) more research in these ecosystems.

A number of other coastal systems are bare following the deterioration of the grass and shrub formations that used to grow over the generally sandy geological formations of the coast. The sand deposits on the shore then are mobilized by the winds and carried inland, or deposited as coastal sand dunes that may invade and sterilize valuable croplands. To counter this, many countries have developed sand dune stabilization techniques on coastal areas. Many forests have been created and now submitted to sustainable management. In France huge pine plantations (*Pinus maritima*) today support a thriving fibre industry and provide a stable and friendly coastline. In North Africa and West Africa coastal sand dunes have been stabilized with similar techniques with *Acacia* and *Casuarina* species; here also these coastal forests stabilize sand dunes, protect and promote rich crop lands which allow fruit tree cultivation and vegetable production and, at the same time, beautify the coast with exceptionally increased potential for touristic developments. This contribution of forestry to the conservation of coastal systems is remarkable and should be further developed in many parts of the Atlantic coasts. The Indian Ocean coast is also exposed to harsh climatic conditions and has the potential of aggressive sand dune formations on the coasts.

Riverine forests are important biological formations that contribute to the conservation of river valleys and the mitigation of river bank erosion; along with the tree and grass formations on slopes on watersheds, they guarantee clear water flows and reduce siltation. In Africa, the gallery forests, in addition to protecting the valley bottoms of many rivers and temporary watercourses, are the refuge of species threatened elsewhere and hold a rich biological plant and animal diversity. It should be noted that flood forests in Africa have especially suffered during the last two decades. The riparian formation of *Acacia nilotica* for example have disappeared along many major low valleys, which means that a number of bared flood plains will be subject to serious wind erosion problems or will be put under inadequate land use. The conservation of these systems requires, however, larger efforts of land-use planning and conservation strategy for which resources are not readily available in developing countries. However some prioritization is necessary for the conservation of major river valleys as a number of major investments are made or are being planned.

4. CONCLUSIONS

Water resources will be most critical in the next century. Growing populations with higher needs per capita as development continues will exert higher demands of this resource. Mountain ecosystems are the prime source of fresh and clean water and it is evident that sustainable mountain development will be one of the strongest challenges to human communities. The call for further attention to the conservation of mountain ecosystems and the promotion of integrative watershed management approaches should be heeded if the challenge of clean water for all, especially the 800 million people that have no access yet to this commodity, is to be met. For this, every effort is necessary to maintain and enhance the protection, conservation and environmental functions of the forests in mountain ecosystems.

The continuum that leads from mountain ecosystems to water bodies that respond to Ramsar Convention of wetlands, through rivers and ground in-flows, should be recognized and large policy measures taken to secure a coherent body of conservation of the water resources. The forests then will be, by the same token, recognized in its various roles to protect, conserve and sustainably use the resources. Necessary efforts should then be taken to enact laws, regulations and conservation and development programmes that are commensurate with the magnitude of the problems posed. Linkages between policies for the conservation of biological diversity and for water resources conservation and management should be made in a clear and effective way, as these are organically connected. The logical consequences of this are the necessary coordinated approach to the implementation of both Conventions on wetlands and on biological diversity.

Forests are important in the restoration of degraded fragile ecosystems of drylands and in increasing their productivity. The coherent set of activities recommended by the convention on desertification include forestry related action such as management of natural forests, particularly with the participation of populations, afforestation and reforestation, and agroforestry practices to support cropland productivity and silvopastoral development. A number of other environmental and protective objectives are also included and have been reviewed by the IPF related discussions and the Consultation on the Role of Forestry to Combat Desertification. Continued support to implementation should now be provided to translate recommendations into practice.

The actions needed in the complex set of natural systems that were reviewed in this document will not be possible if efforts are not devoted to a number of basic prerequisites including i) the improvement of the knowledge of resources involved and the assessment of their situation; ii) the development of coherent research programmes to consolidate or improve technologies; iii) the promotion of regional and international cooperation to exchange the proven technologies and network among specialists; iv) the development of human resources through well-targeted capacity building programmes. The International Conventions that have been proclaimed before or after Rio provide a complete set of approaches and guidelines that should help promote in a coherent manner at national, regional and international levels, the contribution of forestry to the maintenance of a sound environment and to sustainable development.

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