Chapter II Present state of watershed conservation and evaluation of the area

1 Safeguarding watersheds from the viewpoint of natural conditions

1-1 Scope of the study area

The study area extends to 4 to 15 km from east to west and to 44 km from north to south, covering about 90,000 ha. In the east, backbone-type mountains extend in the north-south direction and constitute a watershed for the Antananarivo plain and the tropical rain forest on the Indian Ocean side. As a whole, the study area covers a plateau 1,350-1,700 m high with a complex relief and multiple folds formed by erosion (see figure II-1). The altitude increases from north to south. The two lakes of Mantasoa and Tsiazompaniry are located in the northern and southern parts of the study area respectively. The distance between the two lakes is around 5 km and is a well-folded area at nearly the same altitude, forming a mountainous zone in the east. Rivers flow from south to north, but to west and to east in the zone between the 2 lakes. The western part is being developed, with hamlets and many eucalyptus trees being planted. Towards the south, the hamlets diminish. In the eastern part, the forest is degraded, and grassland and shrubs prevail. At the eastern end of the study area, relatively huge natural forests are found. The entire study area is poor in vegetation. Some believe that it was a wooded savannah in the past, leaving us to think that it has always been poor in vegetation since the beginning. There are few trees, especially in the southern part where the trees are scattered at the edges of crests or valleys. This zone is largely covered by grass.
There has been no significant destruction of the mountainous areas since differences in levels are minor and the slope at the riverbed is relatively mild. However, small traces of destruction were found on steep slopes in the small valley. In the south of the Tsiazompaniry zone, continued traces of destruction are found throughout the length of the waterways flowing from south to north. In general, the mountainside has experienced little destruction and only in specific sites. However, vegetation is scarce and soil erosion is frequent.

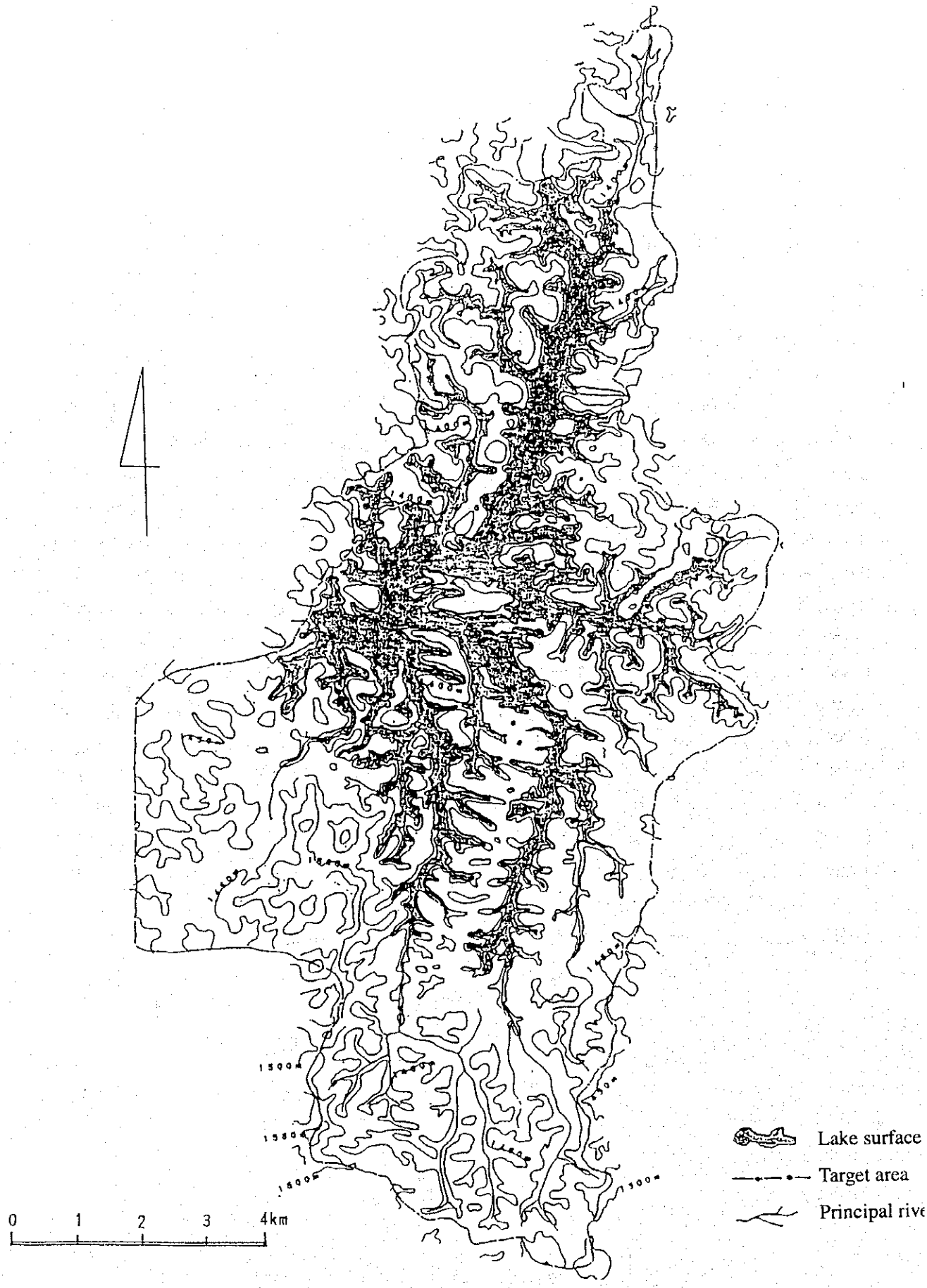


Figure II-1 Map of summit level (1) Mantasoa

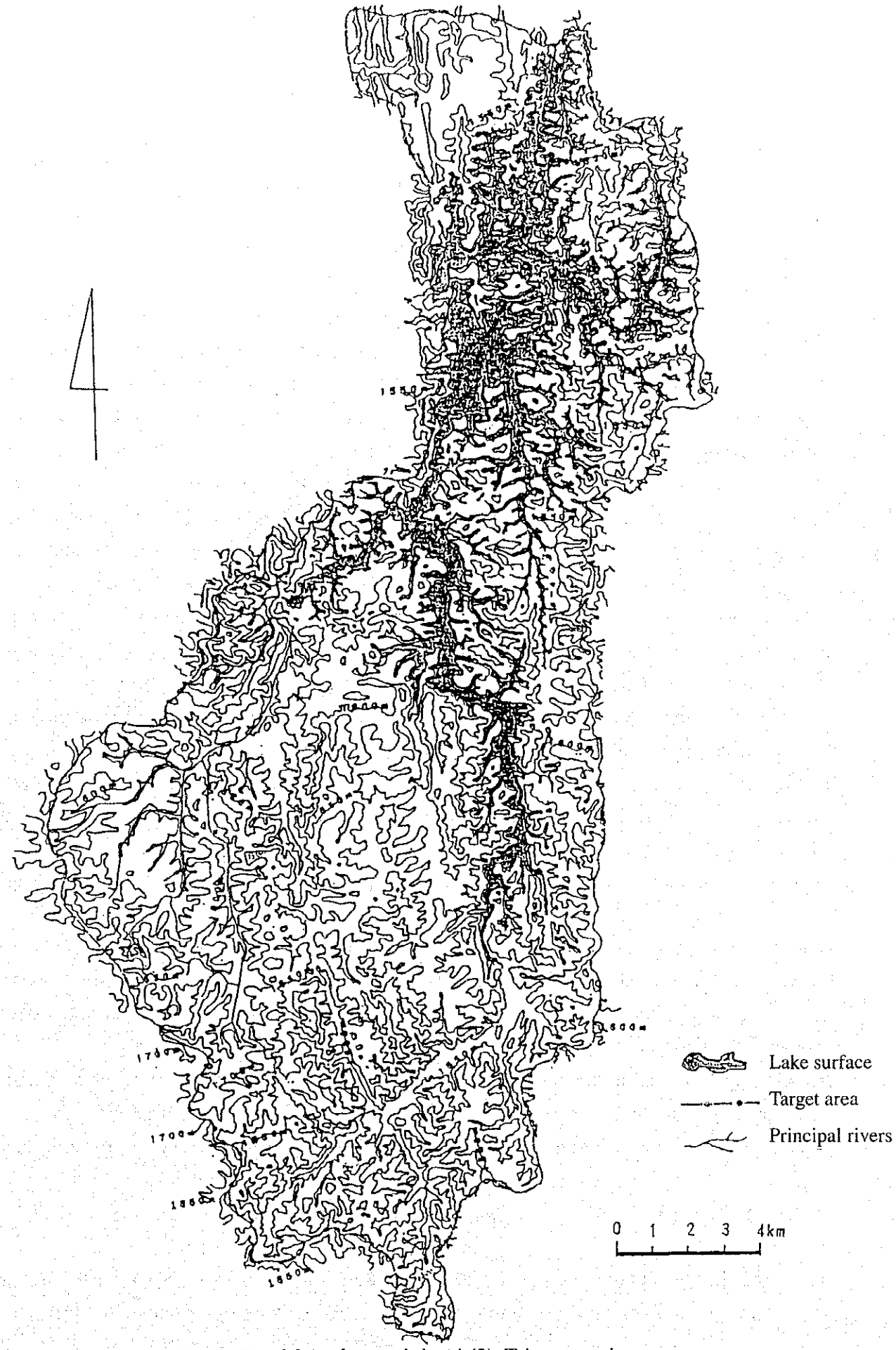


Figure II-1 Map of summit level (2) Tsiazompaniry

1-2 Target area

The target area for the watershed management project in this study is the Mantasoa and Tsiazompaniry lake areas. Table II-1 shows the topographical characteristics of these two zones.

a. Mantasoa zone

With a capture surface of around 9,300 ha, the Lake Mantasoa occupies around 84% of the zone (see Annex 48). The drop is 200 m. Its capture surface is principally found in the southern part. Aside from the southern part, its capture area is very narrow and rains flow directly into the lake. The principal watercourse is found in the south, in two rivers at least 5 km long flowing from south to north and into the lake (see annex 47). Each river has 2 or 3 tributaries. The slope of the bed is mild, around 2%. The principal river is 6.3 km long. Its bed slope is mild, from 0 to 1% downstream, but slightly increases to 3.3% upstream. The average slope is around 2%. Generally, the slope of the first watercourse is 3 to 4%, and 0 to 1% for the second watercourse. Stagnant water and soil may be found at the junction due to the differences in gradient. On the two banks of the watercourses, the hillsides have steep slopes and short valleys. Rains falling on the small valleys flow rapidly into the principal watercourse. The lower part of the small valleys tend to erode with possible landslides. However, since the river slope is gradual, erosion is slow and soil is lost in the river bottom curves. No soil accumulation is visible in the junction with the lake.

The forest vegetation includes natural forests, tree planting, shrubs, bushes, and meadows. Natural trees are gathered in the external and upper parts of the eastern capture zone. Beyond this area, in the west and south, trees with scattered bushes are found at the edges of steep slope valleys and a few in the peak portions. Meadows/shrubs occupy the major part of the capture zone. However, as we go southward the eastern part, there are places rich in vegetation. Much of this vegetation should regrow naturally if there were no fires. Many tree planting are found in the western part, particularly eucalyptus trees, but also some pine trees. In the eastern part, eucalyptus trees are planted on the shores of the lake. Eucalyptus tree planting is in progress in the northern and southern parts.

Land is generally used in the higher parts for tree planting or grazing, for fields (tanety), and terrace planting. In the lower parts, land is used for rice cultivation, with local variations. In the western part, land is rationally used and classified according to altitude. Towards the south however, there is extensive land use. In the eastern part, a few cases of planting on burned land have been found.

If we consider the situation described above from the viewpoint of watershed conservation, aside from the southern part, the capture area is minimal, the valleys are small, and many of

the valleys directly channel rain water, including torrents, into the lake. In this area, rural development progresses in the west where there are many hamlets. In this area, land use has reached its limits and rational management based on the conservation of water and soils is carried out. The tree planting of mountain peaks, not adapted to cultivation, has progressed and the planting rate is high. This certainly explains the low risk of soil erosion. In the northern part, meadows and shrubs occupy a big portion of the land, with significant soil erosion. In the eastern part, meadows and shrubs also constitute the principal vegetation. Even on land designated for tree planting, immigrants have settled and built their own farms. While vegetation is scarce, the added uncontrolled use of the land has incurred the imminent risk of soil erosion in this region. There is a strong need for regulations for use of the land with water and soil conservation.

Table II-1 Topographical characteristics per zone

Elements of the watershed	Mantasoa zone	Tsiazompaniry zone
Surface of watershed (ha) A	11,100	38,100
Surface of capture area (ha) B	9,300	35,000
Lake surface (ha)	1,800	3,100
B/A	84	92
Level variations (m)	1,400 – 1,600	1,500 – 1,750
Relative altitude (m)	200	250
Length of principal watercourse (km)	6.3	18.4
Gradient of the principal riverbed (%)	1.7	1.2
Percentage of forests	29	24

The southern part is certainly the only capture zone in the Mantasoa region. It has soil erosion but it is an essential area providing water reserves. It is subdivided into 3 small watersheds. Each watershed starts upstream at a relatively steep slope. The first watercourse is subdivided into the second and third watercourses, which provide water to the principal course. Since the slope of the principal river bed is mild and long, the speed of soil erosion is slow. However, in areas where the bed slope difference is large, there is risk of flooding from its own waters. Grasslands occupying a huge portion of the watershed have led to the degradation of the area, with poor infiltration of rain water. In some areas, torrents from steep mountainsides have led to soil erosion. To prevent soil erosion downstream and improve the water source reserves, the safeguarding of the watershed through the adapted use of the land, tree planting and fire fighting measures, etc. are indispensable. Since the southern part is virtually the only capture area in the Mantasoa zone, these measures will be very important in the future.

b. Tsiazompaniry zone

The Tsiazompaniry zone has a surface area of around 38,100 ha, and its capture zone constitutes 92% or around 35,000 ha (see annex 49).

The level deference is 250 m. It is around 200 m in the majority of the area. The watershed is wide in the north and south. The southern and south-eastern parts form the biggest part of the

capture zone. Since the western and eastern parts are narrow like in the Mantasoa zone, rain water directly flows into the lake. The principal watercourses are concentrated in the southern part. There are more than 10 watercourses of more than 10 km long. They have many tributaries and run slowly. Almost all flow from the south to the north and drop into the lake. The slope of the beds is mild for the principal watercourses, but tend to become steep upstream. Towards the interior, they tend to constitute a wider watershed in the form of a bag. The principal watercourse is 18.4 km long. For around 17 km from the inlet of the lake, it flows slowly over a bed slope of around 1%. Towards the interior however, for 2 km, the slope becomes steeper at around 3% (see annex 47). The average gradient is around 1.2%. Tributaries in the interior and rain from the banks flow rapidly, but more slowly in the principal watercourse. Sediment production and outflow are expected from small rivers with steep slope and torrents from mountainside, but slope is mild in the principal watercourse and the speed of soil run-off is considered slow. No soil accumulation was noted in the junction with the lake.

In the eastern part, the capture zone is narrow, watercourses are short (maximum 600 m), the bed slope is 3 to 10%, but steep in some areas. In the western part, the watercourses are even shorter (maximum 400 m), the bed slope is around 2 to 3%, but reached 7% in some areas. Forest vegetation is the same as in Mantasoa, but there are more natural forests. These natural trees are concentrated in the eastern and south-eastern parts (see annex 51). In the eastern part, they are concentrated in the eastern side of the watershed running in the south-north direction. In the south-eastern part, they grow in the eastern side of the valley across the watercourse. Among the natural trees in the watershed, we noted many dead trees damaged by forest fires. In other areas, only few shrubs are scattered on the steep slope. The southern part, which constitutes the major part of the capture zone (excluding the south-eastern part), is practically covered with grass. Tree planting develops in the western part and become more and more sporadic towards the south. Eucalyptus and pine trees occupy the entire bank towards the center of the lake. There were traces of coarse cutting of pinetrees at specific points. Pine forests have also been damaged by fires, as the result of which many forest groups have been transformed into degraded tree planting areas. Eucalyptus trees planting by the villagers have progressed from the west to the south, and are now advancing towards the south-eastern part.

The basic type of soil use visible in the Mantasoa zone has been considerably deformed. It is still visible in the western part, but further down the south, use of the land becomes more and more rough. Rice fields and the tanety in low lands are examples of reasonable use from the topographical viewpoint, but distribution of portions per purpose including tree planting areas and grazing land is inconsistent. This is considered to be caused by the fact that there are very few hamlets leaving wide spaces available. In the south, vast grasslands are still left unused.

From the viewpoint of safeguarding watersheds, the situation here is the same as in Mantasoa. Aside from the southern part (including the south-east), the capture zone is narrow. In many

areas, rain water flows directly into the lake. Since the land is used extensively, the risk of outflow of soil is considered higher than in Mantasoa. In particular, many grasslands in the north and eastern parts are suspected to have been used for grazing and since rain water infiltration into the soil is poor, the degree of the outflow of top soil is considered high. The southern part (including the southeast portion) which can be regarded as the only capture zone of the Lake Tsiazompaniry, is subdivided into 4 small watersheds. While the slope of the primary watercourse bed flowing from the mountain sides in the interior has the gradient of 3 to 5%, the slope of the principal watercourse is mild, around 1%, and long. This is why rains provoke temporary floods in areas where the difference in gradient is great. However, the flow is generally slow and soil run-off is minor. But since grasses constitute most of the vegetation, torrents from hillsides cause top soil to flow out. An efficient land use plan is necessary to prevent soil outflow to the downstream area and to improve the recharge function of the water source reserves. Above all, the management of meadows with special attention to the safeguard of the watersheds is essential.

1-3 Soil properties in the target area

First of all in making the watershed management plan, it is necessary to grasp individual topography, what characteristics the land has, and how land is related to vegetation. In order to obtain this basic knowledge, soil surveys were conducted in the target area in May and June 1999, and the following results were obtained. The information gathered provides many suggestions for making an tree planting plan or a detailed design for forest preservation (Data and materials related to the soil surveys are attached in Annexes 38 - 46.).

1-3-1 Profile of soil

(1) Grassland

Grassland whose surface is covered with native grasses has a Layer A of 15 - 20 cm in thickness and, in the lower part, a Layer B containing a lot of weathered/unweathered conglomerate of granite. It is characterized by the accumulation of laminar condensed matter of iron oxide or aluminum oxide. Such a soil layer contains little humus and has a wall-like soil structure without vacant spaces. Therefore, the growth of roots cannot be much expected and the water retention function is considered to be low.

(2) Natural forest

Layer A is considerably thick, and particularly Layer A0 accumulates to a considerable thickness as a result of litter from the ground surface. In Layer B, little conglomerate is found, unlike the soil layer in grasslands. As massive structure develops and has many vacant spaces, it is suitable for the growth of roots, and has sufficient water retention function. This means

that the function for cultivating water sources is high.

(3) Land afforested with eucalyptuses

While Layer A is thick, little development of Layer A0 is seen. The considered cause is that branches and leaves are artificially burnt when materials for firewood and charcoal are gathered. Since eucalyptuses have taproots, the roots extend to the considerably deep part. But, in the soil layer with a conglomerate layer inserted, the growth of roots is hindered, which results in growth of eucalyptuses that is not so good.

(4) Land with Philippia shrubbery

The ground surface is covered with several kinds of moss, and a humus layer is formed by dead moss from the ground surface to a depth of 15 cm. Just under this layer, however, a small conglomerate layer about 15 cm thick accumulates. In the lower parts of this layer, Layers B1 - B3, the accumulation of iron oxide is found sporadically. In such a soil, since the accumulation of conglomerate and iron oxide hinders the growth of roots, it can be regarded that good growth of afforested trees cannot be expected. Therefore, it is possible to determine that land with Philippia shrubbery indicates land unsuitable for tree planting.

1-3-2 Soil solidity and thickness of effective soil layers

A) Soil solidity: Soil solidity in the part near the ground surface is related to vegetation to some degree (see Figure II-2 and 3). Explanations classified by vegetation types are as follows. The northern slopes that receive direct sunlight heat greatly and are dry and have high soil solidity. On the contrary, we obtained the result that harnessing of the southern slope was low.

(1) Grassland

Native grasses of 30 - 40 cm in height grow on the ground surface. As the density is not high, direct rays of the sun reach the ground surface. As a result, the ground surface is dry and solidity is high. In addition, several inserted conglomerate or laminar layers in the soil layer make soil solidity high.

(2) Natural forest

As few conglomerate or laminar layers are contained in the soil, soil solidity shows low values.

(3) Land afforested with eucalyptuses

The formation of a humus soil layer by supplied litter makes soil solidity on ground surface low.

(4) Land with Philippia shrubbery and land afforested with pine trees

The soil layer is thin and immediately reaches bedrock or a unweathered conglomerate layer that has solidity similar to that of bedrock. Therefore, soil solidity on the ground

surface is high.

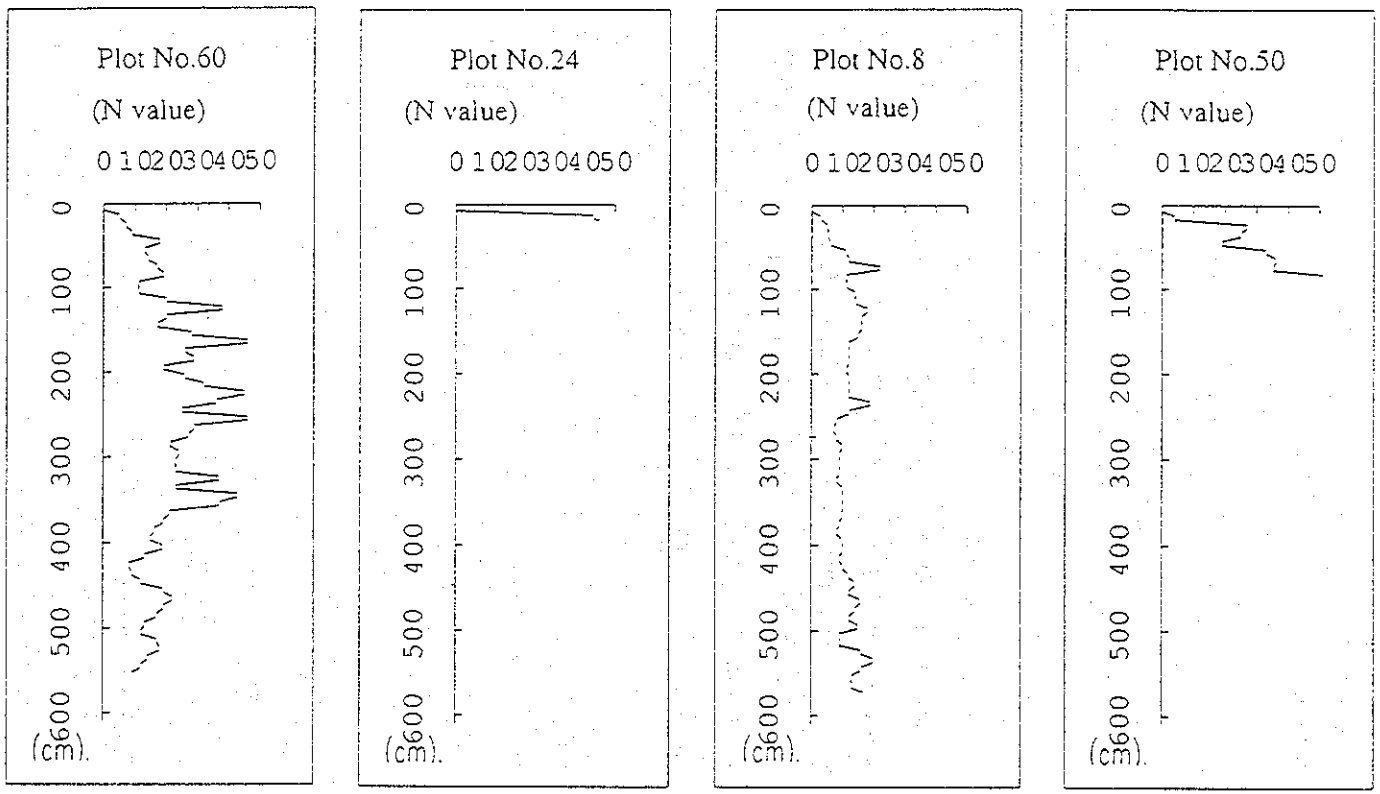
B) Thickness of the soil layer: Except for places with extensive Philippia growth, the relation between vegetation type and thickness of the soil layer is weak. As to the relation to topographical parts, the following results were obtained.

(1) Convex slopes

The soil layer in the upper part of the slope is the thickest, and the soil layers tend to become thinner toward the middle part and lower part. If tree planting is carried out on a convex slope, as the thickness of the soil layer even on the upper part of a hill is high, it is judged that sufficient growth of forest trees can be expected.

(2) Concave slopes

This topography is not often found in the investigation area. In the case of this topography, the soil layer in the upper part of the slope is the thinnest, and the soil layers tend to become thicker toward the middle part and the lower part. Therefore, it is a case contrary to the above-mentioned type. For tree planting, it is recommended to introduce pine trees, which root shallower than eucalyptuses, in the upper part of the slope where the soil layer is thin, and to plant eucalyptuses in the lower part of the slope.



(Grass land) (Grass land) (Natural forest) (*Philippia spp.*)

The N value is the number of blows required for inserting 10 cm in depth a corn resistance body at the edge of a soil intrusion tester. A blow was made by allowing an attached weight to freely fall from the height of 50 cm. In this test, measurements with a unit of 10 cm were repeated until the depth reached 5 m 50 cm at the maximum. When the depth of 10 cm was not reached after 50 blows, measurement was ended.

Figure II-2 Results of simple penetration tests per type of vegetation

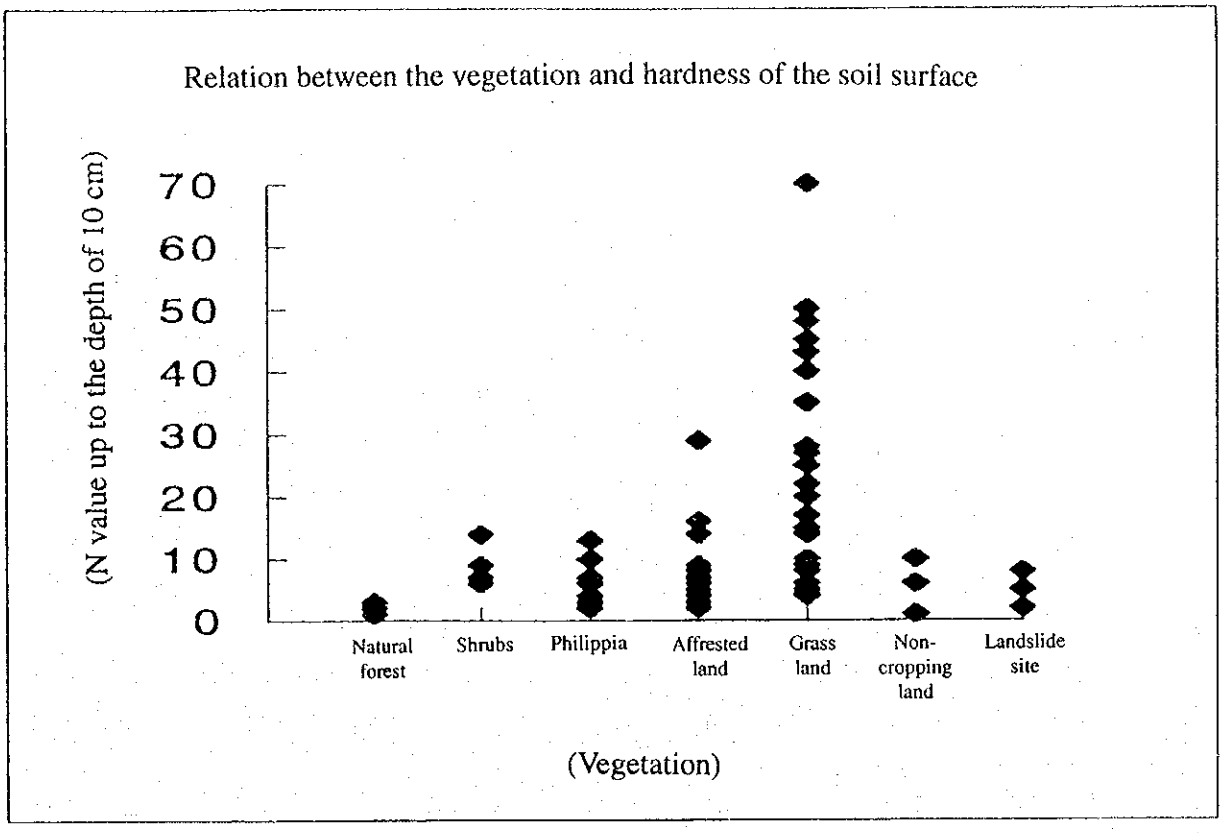


Figure II-3 Relation between the type of vegetation/use of soil and hardness of the soil surface

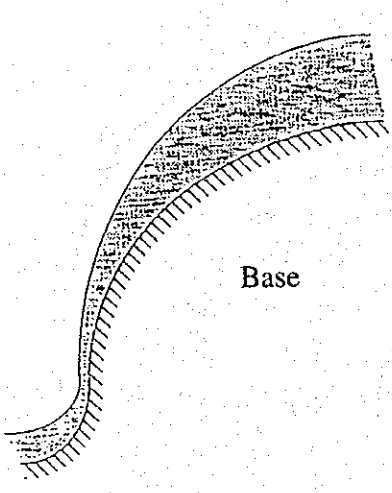


Figure II-4 (A) Relation between soil depth and a convex slope relief

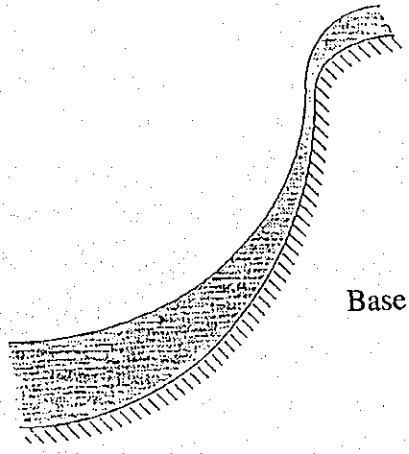


Figure II-4 (B) Relation between soil depth and a concave slope relief

2 Watershed conservation from the viewpoint of socioeconomic conditions

The problem of watershed conservation depends the existing natural conditions. However, as long as people reside in the area, problems due to human activities are of great importance. The following describes the actual situation.

a. Increase of land used privately

In the study area development is oriented into 2 directions: agricultural development from north to south along the western bank of the lakes, and from west to east. Development towards the south is relatively old and orderly accompanying the formation of hamlets. As we go southward, land use tends to be extensive, concentrating only in relatively fertile areas. On the west side of Mantasoa, where the population has been increasing, the land is used efficiently, up to full capacity, unlike in the south. Development towards the east, except one part, is relatively recent. Immigrants have arrived from the west after a reduction of their property due to division in equal parts for inheritance and farmers building their own farms from the west. These are also some former tenant farmers looking for their own land, and those planning to produce marketable crops.

In many areas, the increase in population and the fall of land productivity result in not only easy expansion of cultivated land but also denudation. These phenomena caused the watershed waste. Although there is the possibility that the situation will advance toward the rational use of limited land accompanying the increase in population, it is also easily imagined that development from the west side to the east side will proceed easily.

In the eastern coast of the lake, the rate of landownership is low. The forest must be safeguarded as a precious source of water for the lake. To secure the precious capture zones in the south, it is indispensable to establish a general plan for the land use and aim for an agricultural development to balance with the safeguarding of the environment.

b. Extensive use of the land

Except for the west side of Mantasoa zone, the extensive land use is a phenomenon generally seen. The increase in population accelerates this situation, which then causes a shortening of the fallow period, unnatural crop location and hard driving of the land. As a result, land productivity has fallen. This furthermore results in the disordered expansion of cultivated land and the expansion of denuded land.

In the west side part of the Mantasoa zone, the villagers commit themselves to make rational use of the land after having understood the importance of safeguarding the water and soil. This case is considered to be a good example of use of the land in the study area. To safeguard the watersheds, it will be very useful to disseminate this method to the south and the east. Undisciplined grazing in a portion of the south where the population density is low may cause the erosion of soils and water pollution of the rivers due to absence of trees on the banks.

c. Disorganized cutting of forests

Cutting in natural forests (including shrubs) and tree planting under the Ministry of Water and Forests is visible everywhere. It is clear that this cutting is not authorized and prevents the regeneration of natural forests. If no measures are taken, the remaining forests will also suffer degradation. In the future, this will lead to the exhaustion of water sources. Trees are cut down restlessly in the tree planting and some are left out as mush.

d. Slash and burn practice

Traditionally, the slash and burn method was carried out under certain restrictions within the village society. In recent years, however, this village society appears to have lost its control. The slash and burn method has its purposes, i.e., development of agricultural lands, securing fresh fodder, burning after the felling, etc. However, the resulting propagation of fires has been an obstacle to the watershed conservation. The slash and burn practice produces negative effects on the safeguarding of watersheds, such as the surface soil run-off, deterioration of the rainwater infiltration capacity due to the hardening of the soil, and obstacles to renewal of natural vegetation.

e. Condition of private forests

Tree planting progresses from the north to the south, along the western shore of the lake. It started under the supervision of the Ministry of Water and Forests and continued by the villagers themselves. Their initiative is enormous, even if it was motivated by economic reasons such as the demand for firewood and charcoal. In this area where vegetation has always been scarce, the reasons for tree planting activities were to supply firewood and obtain water for farming. There has been no degradation as mentioned above (paragraph c.). This shows an orientation of the safeguarding activities of the watersheds.

f. Forest management system

The area in the eastern shore of the lake and lands afforested by the Ministry of Water and Forests are both under the authority of the ministry. However, the evident lack of management personnel has overloaded its employees with daily work (issuance of cutting authorizations, etc.). Patrol work at the site has become practically impossible. Without transport means, the efficient management of an extended area is impossible. Since it is not possible to expect an increase in the management personnel, it may be worthwhile to study a replacement scheme using creative means.

3 Evaluation of the watershed

For evaluation of the watershed, discussion was made from the viewpoint of both function to

cultivate water sources and the degree of risk of collapse in the target area. For function to cultivate water sources, attention was given to the permeability of each vegetation type and the amount of water flowing in the dam lake in the small watershed. On the other hand, with the number of places that had collapse as an external criterion, the degree of risk of collapse was anticipated by combining natural environmental factors which seem to be concerned with causes of collapse. This basic knowledge gives subjects to be considered for uses of land and serves as an aid of determination of the Watershed management plan.

3-1 Function to cultivate water sources

3-1-1 Results of the permeability test

As to the relation the between vegetation and permeability, as shown in Figure II-5, we obtained the result that soil of natural forests had remarkably higher permeability than that of other vegetation types. This supports the hypothesis that aggregate structure develops in the soil profile of natural forests, and, as there are many vacant spaces, provides superior function to retain water, as mentioned above in 1-3-1 regarding the soil profile. Conversely, we obtained the result that permeability of grassland was the lowest. As soil structure of grassland has not developed and has few vacant spaces, its function to retain water is judged low.

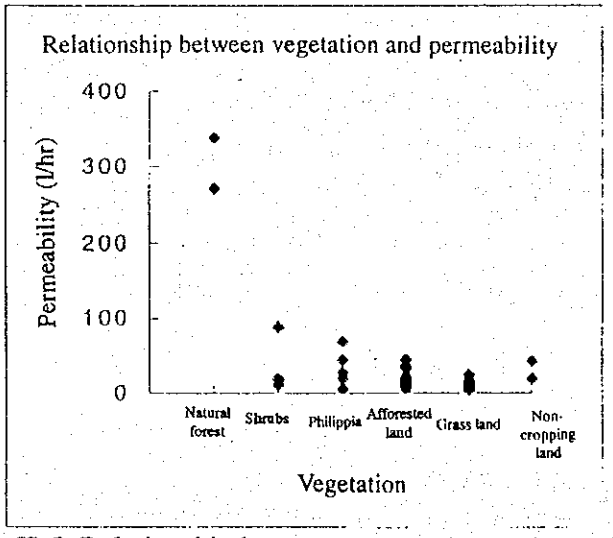


Figure II-5 Relationship between land use/vegetation and permeability

3-1-2 Investigation of flow

Seeing the relation between the ratio of area of vegetation/land use and the flow in each watershed (Figure II-6), the specific discharge is larger in watersheds with the higher area ratio of natural forests where the crown density is 50 % or higher. On the other hand, watersheds with a higher area ratio of grassland have smaller specific discharge. What is pointed out as the water control function of forests is a function to successively decrease the peak flow during floods and a function to stably supply the flow. It was clarified that forests had similar

functions also in the investigation area. In Fig. II-6, Type (a) shows the relation between the area ratio of natural forests with the crown density of 50 % or higher and the specific discharge; Type (b) shows the relation between area ratio of natural forests with the crown density below 50 % and the specific discharge; Type (c) shows the relation between the area ratio of both natural forests and tree planting and the specific discharge; and Type (d) shows the relation between the area ratio of grassland and the specific discharge.

3-1-3 Summary of study results

The study results up to the present have led to the following conclusions:

- The natural forest has a high infiltration capacity which ensures a sufficient water retention capacity. However, the infiltration capacity in grassy areas is low, resulting in insufficient water retention capacity. In afforested areas, the water retention capacity lies between the two.
- There is a negative relation between the surface hardness of the soil and the infiltration capacity. The harder the soil, the lower is the infiltration capacity.
- As the forested surface percentage of the watershed increases, the greater becomes its flow rate.
- A natural forest has a better soil and water conservation function than an artificial forest. A natural forest with high peak density provides even higher soil and water conservation function.

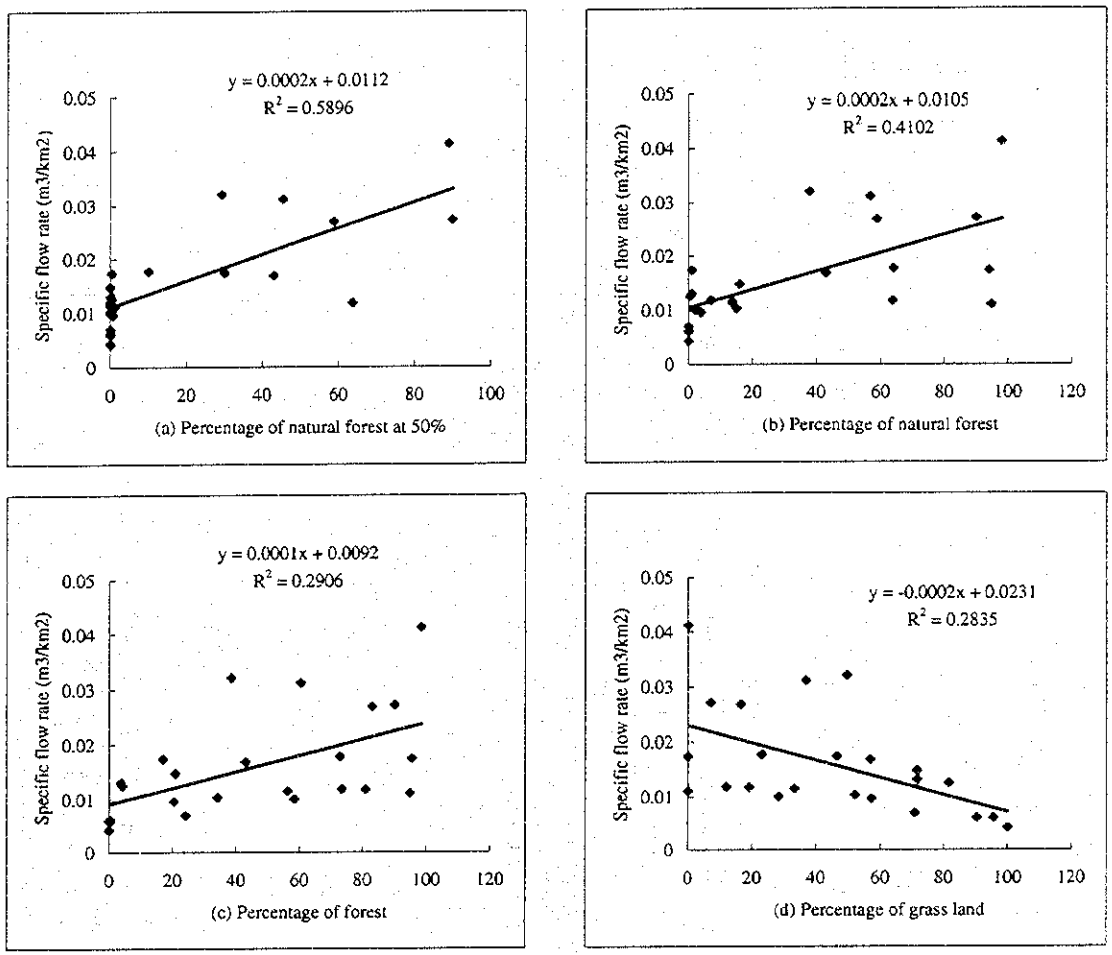


Figure II-6 Relation between the surface percentage of each type of vegetation and flow rate

3-1-4 Evaluation of the conservation of watersheds based on results of the flow rate study

By applying the phenomena mentioned above for the evaluation of watersheds, it was found that the eastern part of the Lake Tsiazompaniry and the southern and eastern parts of the Lake Mantasoa are important areas for safeguarding the dams since natural forests remain in these areas. The natural forest surface area is quite vast in the eastern part of the Lake Tsiazompaniry as compared to other areas (see annex 50). The influence of these natural forests on the soil and water conservation of the Lake Tsiazompaniry is considered to be very important, based on the absolute flow rate of these watersheds. For the Lake Mantasoa, even if the natural forest surface area is smaller in the southern and eastern areas, compared with other areas, the only remaining natural forest are found in these areas and they still play an important role for soil and water conservation.

In other areas such as the northwestern and western parts of the Lake Mantasoa and the western part of the Lake Tsiazompaniry, small natural forests remain on the peaks, and eucalyptus and pine trees have been planted. These play an essential role in safeguarding water and soil. In particular, soil and water conservation capacity of the eucalyptus forests, even if lower than the natural forest, is high as compared to the grassy zones, and therefore they still play an important role.

It must be noted that grasslands occupy a wide surface in the southern and northern parts of the Lake Tsiazompaniry and in the southern part of the Lake Mantasoa. In these zones, insufficient flow rate is expected during the dry season, thus leading to serious water exhaustion problems for farming. Even if the southern area of the Lake Tsiazompaniry represents more than 50% of the water sources, the grassy areas occupy around 60% of the surface, which may affect considerably the water deficiency problem of the lake during the dry season. For the efficient use of these lands, the grassy areas must be rapidly afforested to ensure stable water resources. Based on the points given above, the following measures are considered necessary for the establishment of the watershed management plan.

① Natural forests play an essential role for water and soil conservation, and it is essential to protect them in order to safeguard the watersheds.

② It will be efficient to convert the present grassy areas into forests to increase the soil and water conservation capacity of the 2 lakes.

3-2 Study of landslide possibilities

3-2-1 Method and results of the study

Traces of small landslides are visible in many areas around the Tsiazompaniry and Mantasoa lakes (see figure II-7). At present, these areas are almost entirely covered with grass, which prevents any imminent risk of new landslides, but care must be taken in the future. An

important step for determination of a watershed management plan is to grasp the distribution of the existing places of collapse and to estimate the degree of risk of collapse in this region.
For this study, we examined the aerial photos of the target zone. Among the photos (scale: 1/20,000) taken during the study, and reports on landslide traces, we indicated these on a mesh map, counted the number of landslide spots within each mesh, and established mesh data indicating the number of landslide sites (see figure II-7). We also found a total of 8 environmental factors closely related to landslides: ①rainfall, ②elevation, ③slope, ④direction, ⑤micro-topography, ⑥hydrological system, ⑦geological structure (soil) and ⑧land use/vegetation. Factors related to the relief (elevation, slope, direction, micro-topography and hydrological system) were taken at a scale of 1/50,000 from a topographical map (scale: 1/20,000) established separately in this study. For land use/vegetation, we carried out the same procedure by applying a mesh on the map on soil/vegetation used at a scale of 1/20,000 established separately in this study. The most important elements of the meshes were considered representative of these meshes. Existing data was used for rainfall and the geological structure (soil). Natural environmental factors were divided into several categories to establish a mesh map (see annex 45). A multiple variable analysis was conducted as an external standard on the number of landslide sites per grid, obtained above, to score each category of natural environmental elements. The annex 46 gives a Table of scores for the different natural environmental elements obtained. The range and partial correlation coefficient obtained show that the contribution of the geological structure (soil) and the soil/vegetation use is relatively high for the landslide factors.
We established a mesh map of the expected sliding potential by calculating the score of each category per grid (see Figure II-8). This mesh map shows that areas where landslide is expected are concentrated in the south. If we consider the mesh map indicating the actual sliding sites, this zone contains many of these sites, which demonstrates that the mesh map is quite precise. We therefore noted the difference between the number of expected sliding sites and the number of actual sites on this map (see Figure II-9). It can be judged that areas where a large difference is shown are those which "have the possibility that collapse will increase," that is, whose "degree of risk of collapse is large."

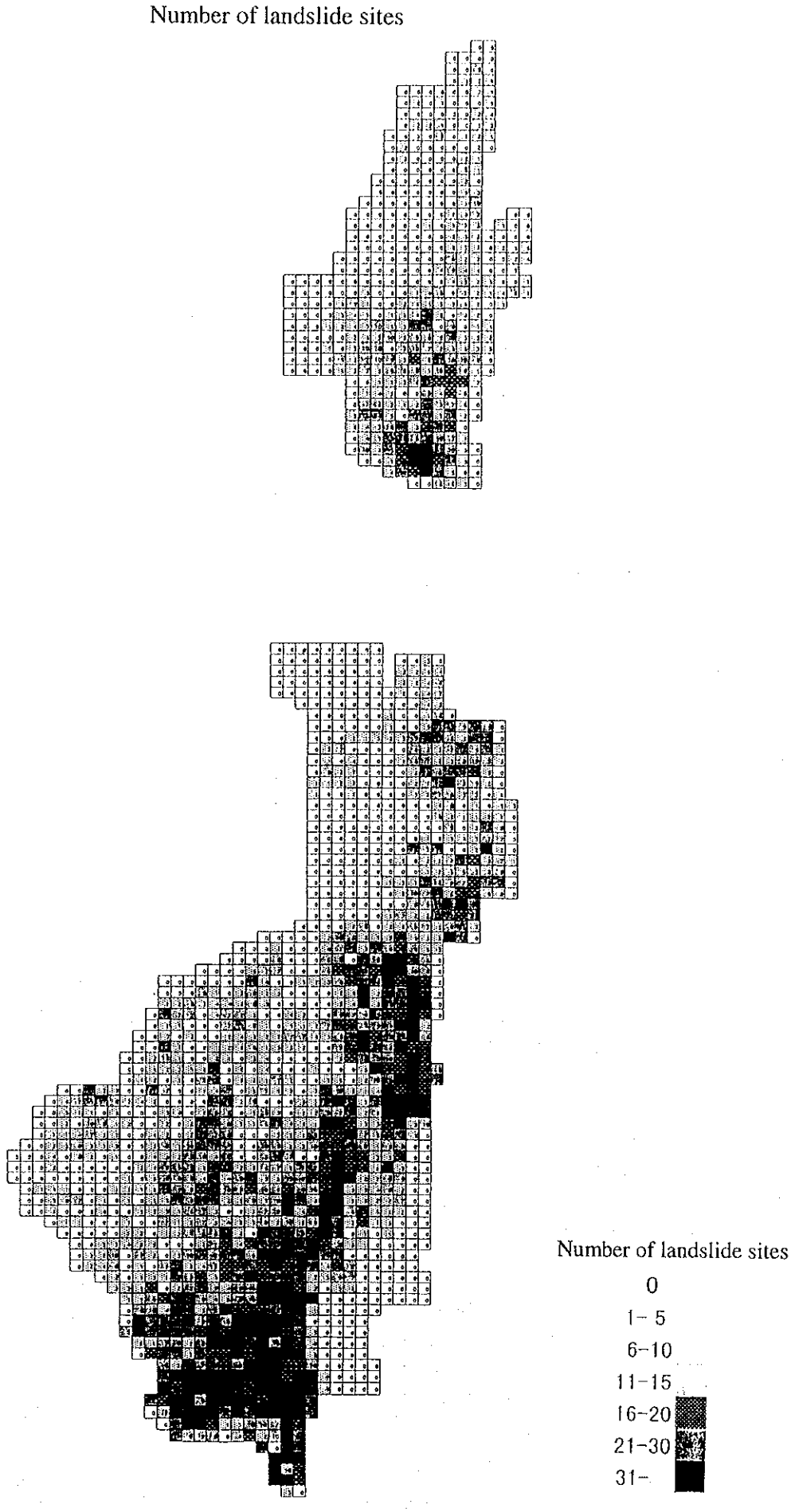


Figure II-7 Mesh data on the number of landslide sites in the two zones of Mantasoa and Tsiazompaniry

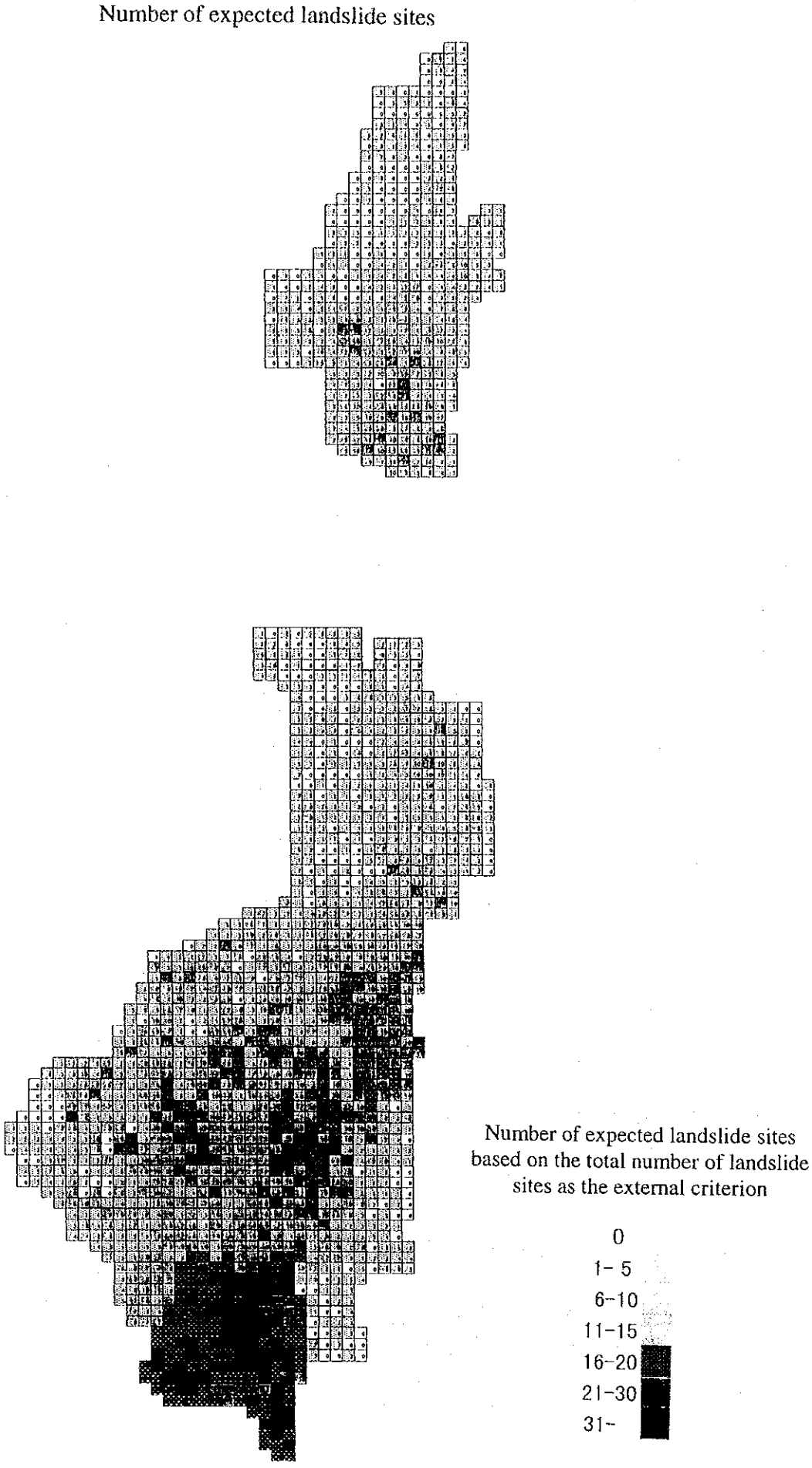


Figure II-8 Mesh map of landslide potential expected in the two zones of Mantasoa and Tsiazompaniry

Difference between the number of expected landslide sites and the number of actual landslide sites

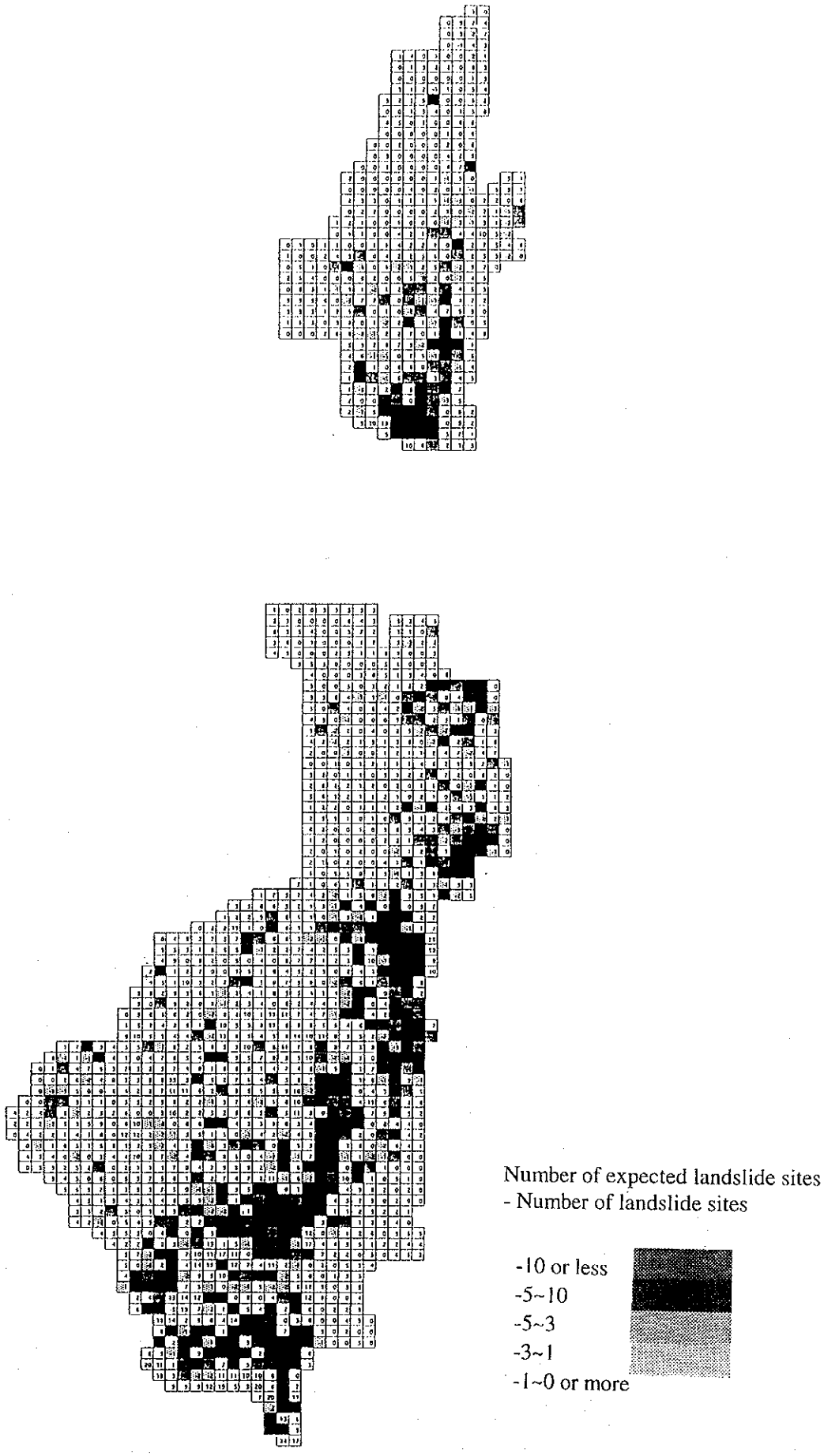


Figure II-9 Difference between the number of expected landslide sites and the number of actual landslide sites in the two zones of Mantasoa and Tsiazompaniry

3-2-2 Evaluation of the conservation of watersheds based on the expected sliding potential

(1) Mantasoa zone

Actual sliding areas are concentrated in the shrub and grassy areas of the southern part of the Mantasoa zone (zone D). If we consider the number of expected sliding sites, even if there are differences with the actual situation, they tend to be more numerous in the southern zone. In other zones, they tend to be slightly higher than at present in the eastern shore of the lake Mantasoa. In the western shore of the lake Mantasoa, the number of actual sites and those with sliding potential are both low.

If we consider the difference between the actual number and the expected number of landslide sites, the figures tend to be greater in the southern part of the lake Mantasoa.

This shows that the sliding potential which remains high up to the present in the southern part of the Lake Mantasoa, principally occupied by grassy and shrub areas, must be taken into account during the establishment of the plan. The second zone at risk is the eastern shore of the lake (zone E). The area with the lowest sliding potential is the western shore (zones B and C), with the potential diminishing in the order of the southern part, the eastern shore, and the western part.

(2) Tsiazompaniry zone

Around the Lake Tsiazompaniry, the southern part of the target area (zone D) and the eastern shore of the lake (zone E), contain many sliding sites. The expected sliding sites tend to concentrate in the southern part. The tendency is also relatively strong in the eastern shore along the lake from the southern part. However, the number of actual sliding sites is not as many in the western and northern parts (zones A to C). The same applies to the expected sites. In this zone however, the sliding is relatively significant throughout the length of the fault practically in the north-south direction of the western shore of Lake Tsiazompaniry and the western part of Analamihoatra (zones C to D)(see Chapter 1, 1-2-1 Topography Relief). The presence of these sliding sites due to the fault also appears in the number of actual sliding sites. This is unique of the western part where the sliding sites must are supposed to be few. The difference between the number of actual sliding sites and the expected number shows that the zones with high figures exist successively towards the southern part of the Lake Tsiazompaniry at the eastern shore (zones D to E). In the surrounding areas of the Lake Tsiazompaniry, it was concluded that the number of sliding sites is significant from the southern part of the area to the eastern shore of the lake. The number of expected landslides is also high. During the establishment of the watershed management plan, the landslides in this area must be taken into account. In other parts of the study zone, the actual sliding potential is low and is expected to remain so in the future. But as indicated above, in the western part of the study zone, there were a series of landslides due to a fault. This factor must be taken into

account for the zone on this line (linear structure of the relief).

4 Problems in watershed conservation

The present safeguarding condition for the watersheds has been explained in the preceding paragraph, with a summary in Table II-2.

If we consider the natural conditions, the fragility of the natural vegetation is a problem. There is very few natural wood left. The predominance of shrubs and grasslands, or areas without trees, has led to much surface erosion. Furrow erosion on the hillside may develop into gully erosion. First of all, it will be necessary to protect the existing natural forests and to assure the renewal of vegetation artificially or naturally. Although the relief is complex relief due to soil erosion, if we exclude certain areas where level difference is minor and localized, this does not seem to have a major effect on the safeguard of the watersheds.

From the socioeconomic viewpoint, we may cite problems such as land use, the absence of forest management, the population increase, and the relative reduction of cultivated land due to the increase in population.

Land use:

Planting on slopes, existence of wide spaces without forests, uncontrolled grazing and slash and burn planting may be cited as problematic originating from traditions or customs. It leads to decreasing land productivity. It will therefore be necessary to study more appropriate land use to ensure the watershed management. Improvement of land productivity is essential as well as the efficient land use. Effective watershed management can be realized through a participatory method that is designed to help the villagers recognize and solve problems by themselves.

Absence of forest management:

The illegal cutting of wood and forest fires are the problems to be addressed by the Ministry of Water and Forests. In reality, however the lack of management personnel has led to insufficient supervision. Since an increase in personnel is not expected at present, the management capacity of the Ministry of Water and Forests is limited. Creative means to resolve the problem such as the measures recommended by ZODAFARB must be applied.

Population problem:

It can be considered that the factors of watershed waste are inappropriate land use and an increase in population. One of the causes that forces inappropriate land use is the sudden increase in population. Even if proper means for land use are applied, the purpose of watershed management will not be achievable. Therefore, it is necessary to start family planning as part of the watershed management activities. In order to realize practically effective family planning, what is indispensable is empowerment through the active participation of women in watershed management and execution of planning with

promotion of the improvement of women's social and economic status. It is necessary to discuss original and inventive measures.

Relative reduction of farmlands due to population increase:

Demographic growth has led to the relative reduction of farmlands, etc. This is why the villagers easily migrate from west to east of the lake to find land where they can set up their farms. Since use of the land in this vast region tends to be extensive, this has led to soil erosion. Safeguarding of the land to secure water resources in the future is particularly recommended in the eastern part. Measures must be taken to give priority to the maintenance and improvement of production from land already cultivated in the west to reduce the pressure for development towards the east.

The above-mentioned problems link directly to production activities of the inhabitants. Watershed preservation will not be effective if each of these activities is individually grasped; it must be worked on with the production activities of the inhabitants regarded as an overall and comprehensive subject. Therefore, it is considered that the objective of this watershed management plan is to work on problems extending over various fields under a comprehensive plan with the participation of the villagers.

The intensive land use, including slope planting and tree planting to secure water resources are recommended to safeguard the watersheds is being carried out in the western part of the Mantasoa zone. Land use to safeguard the water and soil and the rational use of slopes are good examples and methods of the proper land use, which must be largely disseminated. Furthermore, the villagers of this region actively support tree planting. It will be necessary to establish a motivating watershed management plan to encourage such support.

Table II-2 Present conditions of watershed conservation

1 Obstacles

Present situation	Problem	Context
Existence of wide spaces without forests		
Use as grazing land Shrub/grass lands	Increased surface erosion Pollution of rivers Origin of forest fires	1. Traditional land use 2. Absence of an overall plan for land use 3. Absence of guidelines for land use 4. Insufficient financing for tree planting (Ministry of Water and Forests)
Planting on slopes		
Tanety in grasslands	Outflow of soil Decrease of land productivity	1. Traditional land use 2. Absence of cultivation guidelines by farming technology training organism 3. Population increase
Illegal cutting (national forest)		
Wood-shrubs/bushes	Reduction of capacity to regenerate vegetation	1. Gathering of materials for charcoal

	Rapid increase of grasslands Outflow of soil	2. Lack of management personnel 3. Unawareness of villagers to the common good 4. Collection of traditional materials for family consumption
Wood - tall trees Tree planting	Reduced capacity for regeneration Degradation of forests	5. Complexity of the procedure to obtain cutting license
Forest-country fires Wood-natural tall trees Wood-natural bushes/shrubs Shrubs/grass lands	Reduced capacity for regeneration Degradation of forests Reduced capacity to regenerate vegetation Acceleration of transformation to grasslands	1. Lack of forest management personnel 2. Ignorance of villagers regarding forest fires 3. Reduction of the self-management capacity of the village society
Uncontrolled livestock breeding Slash and burn on grass lands Absence of protected forests	Accelerated surface erosion Degradation of soils Outflow of soil and increased risk of landslides Pollution of rivers	1. Supply of fresh grass 2. Absence of guidelines for management of pasture 3. Reduction of the self-management capacity of the village society
Migration, farming away from home	Extensive land use Private and uncoordinated land use	1. Reduced farmland due to population increase and division into equal parts of inheritance 2. Absence of agricultural guidelines
Slash and burn planting	Degradation of natural forests	1. Absence of forest management 2. Traditional planting methods

2. Elements to be promoted

Present situation	Advantages at the watershed management level	Context
Planting on slopes Intensive land use (Rational land use based on slopes)	Minimized soil erosion	1. Maximized land use in the region following population increase 2. Living know-how based on experience
Enlargement of private tree planting	1. Prevention of soil erosion 2. Improvement of soil and water conservation 3. Increase in the percentage of forests	1. Fuel requirements in urban areas 2. Provision of firewood and construction wood for family use 3. Safeguarding of water and the soil
Tree planting of water source areas	Recharged water reserves	Water supply for agricultural use

Chapter III Initial environmental study

The Initial Environmental Study (IEE) is a summary study to judge whether the environmental impact assessment (EIA) is required or not. In other words, the potential effects of the different activities in the participatory watershed management plan on the actual environment will be initially studied. Based on this study, the necessity of an in depth environmental impact evaluation will be determined.

This study covered the following points.

① Activities under the watershed management plan in accordance with the objectives of the present study

② Environmental situation in the target zone of the plan

③ Potential impact on the different environmental elements

1 Content of the study and activities

The purpose of the watershed management plan of this study is to re-establish and safeguard deteriorated watersheds through adapted land use in harmony with the natural environment of the watershed and as a whole. Land use will ensure the safeguarding of the water and soil by the villagers. As such, the objective of the study is to formulate a participatory watershed management plan, based on local conditions and an overall plan for the watershed and its surroundings.

This will be concretized by implementing the PS and the principal components obtained during the first part of the PS study, as follows:

① Production of nursery trees: Nursery trees are produced for tree planting, by small and simple nurseries around the homes

② Tree planting: The objective is to produce firewood, charcoal, feed trees, and small groves for grazing lands

③ Cuttings: Trees will be cut to manufacture charcoal

④ Manufacture of charcoal: Afforested trees are used

⑤ Agroforestry: Planting of quickset hedges in tanety planting areas

⑥ Transport of farm and forestry products: Transport to the market of charcoal and forestry products, etc.

⑦ Clearing of farmland: Clearing of fields and rice paddies.

Potential impact on the environment caused by the implementation of these plans will be considered.

2 Present environment

Paragraphs 2 and 3 of Chapter I provide details on the natural environment and the socioeconomic environment of the target areas of the watershed management plan, with the following particular characteristics.

Natural environment:

Climate

The eastern part of the central plateaus has a highland monsoon climate. The watershed area in the east has a rain forest climate. Annual average rainfall is 1500 mm, with an annual average temperature of 17°C.

Vegetation

The natural forests are dispersed near the watershed in the east, and are grouped towards the south-east. Many of these natural forests are covered with moss. There are many tree planting in the west. In other parts, grasslands and shrub thickets extend widely.

Relief and topography

Hills with an altitude of 1400-1700 m have complex foldings due to the effect of erosion. The Mantasoa and Lake Tsiazompaniry are located in the center. In principle, the rivers flow from the south to the north. There is a medium-scale waterfall at the southern end of the Lake Tsiazompaniry, which creates a picturesque site with the surrounding natural forest.

Hydrographic network

The two lakes divide into various courses which flow into the Ikopa river crossing the Antananarivo plain. Rivers from the northern end of the Lake Mantasoa are used for power generation, then flow in to the eastern coast. Small watercourses flowing into the two lakes are used as important water sources for farming activities. The villagers use the two lakes for fishing.

Air

All roads in the study area are not paved and used by a very limited number of vehicles. As such, the effect of exhaust gas is minimal. During the dry season, dust clouds produced by passing vehicles are considerable but momentary.

Biological environment

The southern end of the Lake Tsiazompaniry serves as a habitat for aquatic birds. No other precious biological entities requiring preservation are found.

Socioeconomic environment:

Land ownership

The western part of the study area has long been private properties or used for private use by the villagers. Other lands are owned by the State, such as the Ministry of Water and

Forests.

Land use

In the hamlets, lands are basically used as rice fields in the lower areas, as terrace fields, tanety, tree planting and grazing. According to the density of hamlets, this model has been largely deformed to be extensive. On the west side of the lakes, the villagers express the need for tree planting, and tree planting develops towards the south. Migration or creation of farms by villagers from west to east of the lake is progressing.

Economic activities

Even if there are some leisure industries such as hotels, major activities are in the primary sector: Agriculture, forestry (principally charcoal production), fishing, etc. Cash revenue is principally obtained from charcoal, potatoes and fishing products. Some villagers are wage earners.

Local villagers

They belong to the Merina ethnic group, who principally practices farming and grazing. With natural forests in the eastern shore of the lakes, there are few ethnic minorities who traditionally practice the slash and burn method.

Medical environment

Clinics are only found in the county town.

Educational environment

There are public and/or private primary schools in the fokontanys.

As a whole, no zone in the watershed management plan has specific environmental conditions requiring special attention, aside from the wild bird sanctuary at the southern end of the Lake Tsiazompaniry.

3 Potential impact

We have studied the potential impact of activities under the watershed management plans, defined during this study for the environment of the region at each stage of implementation and management. An environmental model (Table III-2) was used to foresee these potential effects. In this model, the potential effects were divided into 5 levels according to their degree of impact, as defined below.

P: Positive impact is expected.

A: Negative impact is expected.

B: Slightly negative impact is expected.

No indication: No particular impact

Table III-1 Model to evaluate the environmental impact

Environmental factors	Activities						
	Nursery tree production	Planting	Cutting	Agroforestry	Charcoal production	Transport of products	Development of farmlands
1. Social activities							
* Daily life of villagers							
Forced migration							
Unauthorized migration	P	P		P	P		P
Changes in way of life							P
Conflicts between villagers							
Natives, minority ethnic groups							
* Population problem							
Population increase							
Sudden change in the composition of the population							
* Economic activities of villagers							
Change in bases for economic activities							
Reconversion of economic activities, unemployment		P	P		P		
Increased differences in revenue		B	B	B	B		B
* System, customs							
Reorganization of the land use rights							
Modification of the social structure, reorganization, etc.	P	P	P	P	P		P
Renovation of existing customs and systems	P	P	P	P	P		P
2. Health and sanitation							
Increased quantities of pesticides used							
Emergence of endemic diseases							
Propagation of contagious diseases							
Accumulation of harmful product residues							
Increase of waste materials, excrements							
3. Landscape, etc.							
Loss of precious scenic sites		B					B
Influence on buried resources							
4. Precious biological species, ecosystems							
Change in vegetation		B					B
Effect on precious species, characteristic fauna and flora		B			B		B
Reduction of plant diversity		B					
Introduction and proliferation of harmful organisms							
Loss of humid areas, peat marshes							B
Degradation of the natural forest		P	P	P			
5. Soil, land							
* Soil							
Soil erosion		P		P			B
Soil salinization							
Loss of fertility		P		P			

Soil pollution			B		B		B
* Lands							
Land destruction		P		P			
Emergence of devastated lands		P		P			
Reduction of functions such as protection against wind, sand, fires, etc.		P					
Land subsidence							
6. Hydrology, water quality							
* Hydrology							
Change in surface watercourses		P	B		B		
Change in watercourses and levels of underground waters		P					
Drying and floods		P		P			
Raising of the river bed		P					
Effect on fluvial transport							
* Water quality and temperature							
Water pollution, drop in quality		P		P			B
Eutrophication							
Penetration of salt water							
Change in water temperature		P					
* Air							
Air pollution					B	A	
Generation of CO_2		P			B		
Change in the micro-climate		P					
Noise emission						A	
7. Durability of forest resources, functions of the forest							
Durability of material resources		P					
Broken durability of functions to safeguard the environment		P		P			

In this section, the expected potential effect on the present environment of the watershed management plan is considered at 3 levels during each stage of implementation and management stage of the plan.

a. Type and source of the effect
b. Degree of influence on defined environmental elements
c. Existence of improvement measures, follow-up period, frequency, scope and adaptation of improvement measures.

The implementation of the plan may create the following effects on the environment:

Land use:

Planned use of the land by the villagers themselves will resolve the disordered use of the land at present. Consequently, tree planting in grassy areas or those used extensively will allow the renewal of degraded soil and improve land productivity. Aside from the rational land use as shown in the western area of the Lake Mantasoa, the promotion of agroforestry will reduce top soil outflow of farmlands and will improve productivity of the land.

Soil:

The potential impact on the land will consist of the building of nurseries, development of tree planting land, the provision of furnaces for charcoal production, the clearing of farm lands, etc. Possible effects are the accumulation of eroded soil in small water courses, air pollution from dust, etc. However, these operations are short, temporary and have already been carried out. Their frequency will certainly be greater than in the past, but this is not considered as serious problem. The extension of agricultural lands will increase soil run-off during the rainy season. The overall promotion of tree planting and the introduction of agroforestry methods should improve the present extensive use of the land. Proper management is necessary, for example, through measures against surface soil run-off by planting trees based on contour farming on vast pasture areas to protect the soil.

Water quality:

No road development activities are scheduled. Only very small nurseries will be established. Work will be carried out during the dry season. The proper clearing and levelling of land will limit soil run-off during the rainy season to a minimum, and will likewise protect the quality of water. The use of chemical products for planting is possible temporarily. Proper management can reduce infiltration to neighboring areas.

Air:

The present roads are mainly unpaved. As such, dust pollution is expected during the transport of farm products to the markets. The development of artificial forests through tree planting must generally improve air quality by enhanced of dust clarification. Charcoal production will also lead to air pollution, but it can similarly be considered as minor problem.

Noise:

No particular noise with a negative effect on the environment.

Biological elements:

In this area, vegetation is very poor and natural forests are rare. Grass lands and shrub thickets occupy most of the surface area. The rational land use will be promoted under this plan. Unproductive planting areas and grasslands will be transformed into tree planting or farmlands. This will modify the natural vegetation. In addition, conversion to arbors is favorable to safeguard the watersheds. The effect of tree planting to the lake area and aquatic organisms including fish, is likewise recommended. However, reservations for wild birds and the waterfall area at the southern end of the Lake Tsiazompaniry must be excluded from the development zones.

Socioeconomic environment:

Even if in principle, the way of life of the villagers will not be modified by the extension of tree planting and farm lands, The increase in soil productivity, etc., will be consolidated. Cash income may be increased. The willingness of the villagers to

participate in the plan or not may lead to differences in revenue. Migrations to other regions should be reduced, thus increasing the population in the area. To establish this plan, measures to increase the population in the future must be studied.

These will be the potential effects of implementing the plan. Activities under this plan will include the development of the watersheds through rational use of the land. Procedures for more rational land use to safeguard the water and the soil and the use of biological resources will be promoted in the area occupied by the villagers. This will not basically change the way of life of the villagers but will improve the present land use system. Consequently, the plan will not basically change the actual environment but will contribute to the improvement of the natural environment through the use of biological resources. The conversion of damaged soil due to unproductiveness to more productive use must contribute to the development of the region.

The potential impact of implementing the plan on the environment may be minimal. Therefore, it was judged that there was no positive reason for conducting an environmental impact evaluation study (EIA) separately from this study.

Chapter IV Watershed management plan

1 Principle of watershed management

The watershed management plan is established for the target zone. The Mantasoa and Tsiazompaniry watersheds play an important role as a water source for both the villagers in the area but also for the Antananarivo metropolitan zone. The conservation of watersheds will be ensured by coordinating the following local elements: forest, water, soil and the way of life of the villagers. In other words, the durable management of the watersheds will become possible by globally ensuring the prevention of outflow of soil, water conservation, and the way of life of the villagers. The basic principle is proper land use to safeguard the environment. Land use in all the watersheds including forests, must be balanced.

Therefore, the approach to the watershed management plan for which this investigation is to be used should be implemented from the two points of view: a watershed management from the viewpoint of the whole watershed, and from the viewpoint of the lives of villagers who live in this region. What is particularly important is the adoption of an approach based on the viewpoint of proper land uses that will lead to restraint of increase in population and to improvement of land productivity, both of which are subjects of watershed preservation. In order to harmonize the interests of the whole and of the individuals, a participatory watershed management plan was made based on the results of pilot study (hereinafter referred to as "PS") according to classification of watershed management viewed from a standpoint of the whole watershed. (For pilot studies, see Part 2.)

From the viewpoint that factors of watershed waste are an increase in population and inappropriate land use, the participatory watershed management plan should be executed on the basis that villagers' lives will be improved through solution of population problems by taking measures against them and improving land productivity by appropriate land use. On the other hand, the security of durability is important for the watershed management plan, and it is indispensable that watershed preservation activities will be anchored and executed in villagers' daily lives. For this purpose, women's participation and the improvement of women's status are especially required.

Therefore, this plan should be made to contribute to the improvement of women's status by stimulating their participation in watershed management activities, raising women's ability to participate in social activities and promoting the improvement of poverty alleviation and empowerment.

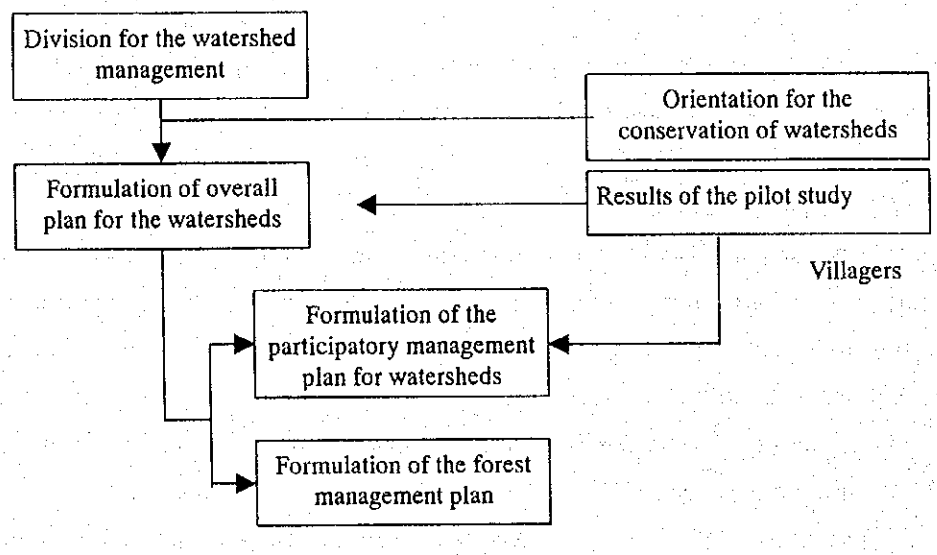
It is considered that only when this is achieved, the practically effective family plan and continuous watershed management can be realized.

2 Procedure for the formulation of plans

The points below are defined as the concrete illustration of the watershed management plans.

① Division for the watershed management
② Measures for the conservation of watersheds
③ Overall plan for the watershed management
④ Participatory management plan for watersheds
⑤ Forest management plan

The study of these points will be carried out in the following order.



3 Zoning for the watershed management

For the watershed management in Mantasoa and Tsiazompaniry, the conservation of forests appears to be the most important element in order to secure water sources and to prevent outflow of soil. Even if there are differences in population density per zone, many villagers live in the watersheds of these two lakes. The watershed management must therefore be carried out based on the living zones of the villagers. Since population density varies according to areas, a uniform development of the watersheds will not be recommended. It is materially impossible for the villagers to carry out a participatory plan within an area where they are not residing. As such, we think that it will be realistic and rational to manage the watersheds by dividing them into major parts as indicated below, based on the population density (see Figure IV-1).

① Area for the participatory management of watersheds
② Forest conservation zone

The watershed management zone with participation is an area where it will be advisable for the villagers to develop their watersheds through their production activities. In this case, the villagers will play a principal role in development. Since the villagers will manage their watersheds within the context of their production activity, they will be responsible for ensuring the conservation of the watersheds or not. Consequently, the establishment of plans through the participation of the villagers and correct guidelines and implementation are essential. In the forest conservation zones, its relation with the daily life of the villagers is very limited. In the future however, maintenance can be assured for the forest to provide water resources from the lakes. To maintain the forest, if it is possible to carry out overall management with the villagers based on topographical conditions, the methods for application will be studied. In the future, it will be essential to guarantee the water resources in the lakes by safeguarding the forest. The Ministry of Water and Forests will play an essential role for the overall management.

Table IV-1 indicates the surface covered in the two zones.

Table IV-1 Surface per management division

Unit: ha

Management division	Participatory management of watersheds	Forest conservation	Total
Mantasoa	6,652 (72)	2,641 (28)	9,293 (100)
Tsiazompaniry	32,479 (93)	2,525 (7)	35,004 (100)
Total	39,131 (88)	5,166 (12)	44,297 (100)

Note: Water surface excluded. ( ) indicate percentage (%). * Participatory watershed management includes ZODAFARB target area of 2,330ha (1,158ha of Mantasoa and 1,172ha of Tsiazompaniry) which is eastern area of the lake managed by Ministry of Water and Forests.

If we consider all the watersheds, the zone covered by the participatory watershed management plan represents 88% of the forest conservation zone and 12% of the total.

4 Guideline for the conservation of watersheds

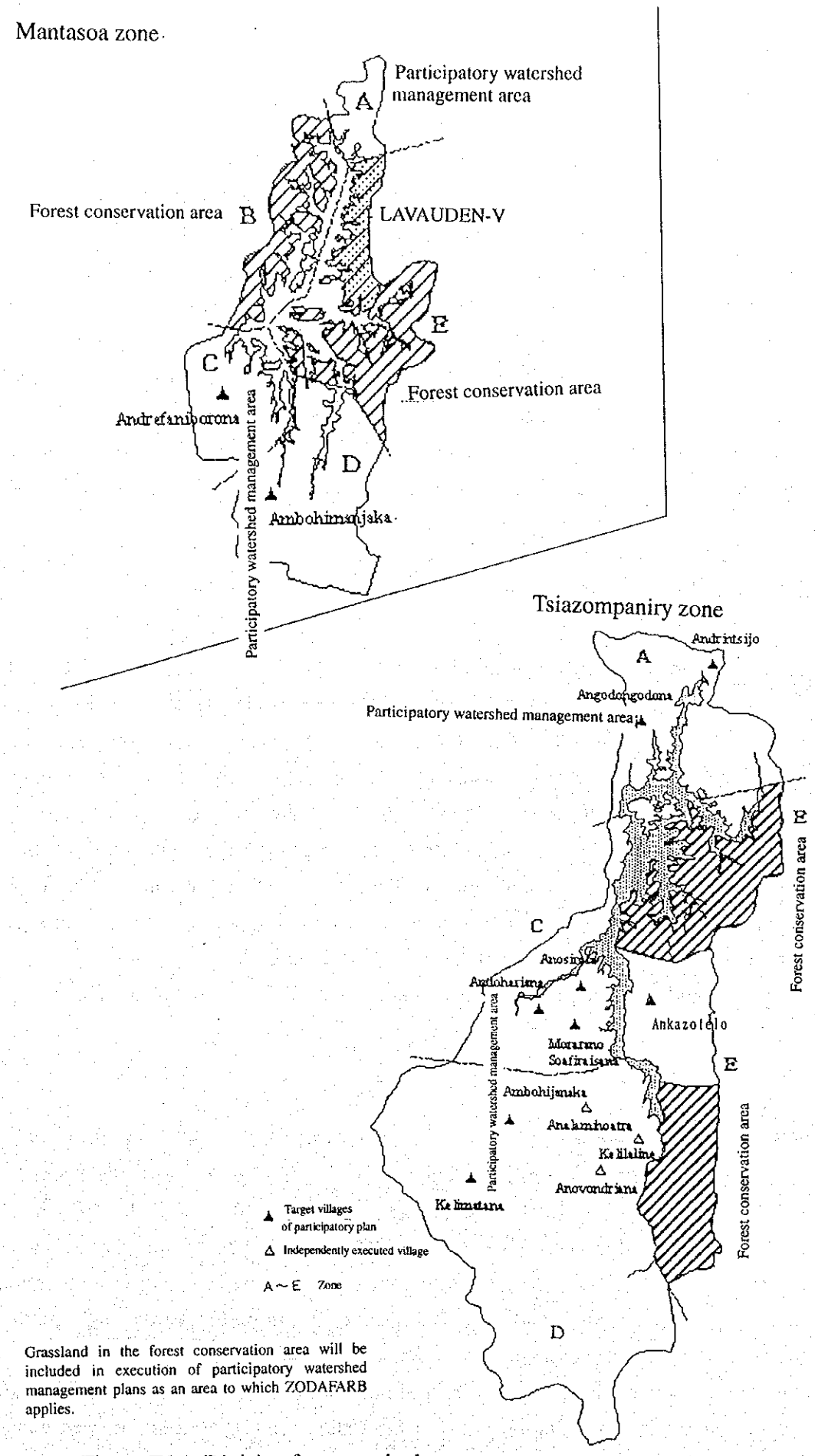
Based on the evaluation of the watersheds in Chapter II, the orientation to be considered for land use to preserve natural conditions is as follows. The following elements must be considered to establish and implement the watershed management plan and the forest management plan.

Watershed management zone with participation

(1) Mantasoa zone

The watershed management area with participation, which represents around 70% of the lake supply watershed area, is stable from a topographical viewpoint, except for the southern part (zone D). The percentage of forest is also high. However, these forests are artificial ones

created at the same time. There are only few examples of natural forests in the southern part. Rivers supplying the lake are big and almost all originate from the southern area and flow to the north into the lake. To manage the watersheds, ① Outflow of soil must be prevented to safeguard farm lands. ② The percentage of forests must be increased and farming on steep slopes must be avoided since the sliding potential is high in the southern area. These areas are covered with Philippia in the north (zone A), the soil layers are thin and not adapted to agriculture. They should therefore be left as is while waiting for the introduction of new types of vegetation.



Note: Grassland in the forest conservation area will be included in execution of participatory watershed management plans as an area to which ZODAFARB applies.

Figure IV-1 Division for watershed management

(2) Tsiazompaniry zone

The participatory watershed management, which represents around 90% of the lake supply watershed area, has a huge influence on the conservation of the dam. In particular, the watershed surface is huge in the southern part (zone D), with a huge volume flowing into the lake. For this area, we must ensure management of land use by the villagers and the conservation of water and the soil. In concrete terms, ① The natural rare forests subsisting in the banks of small watercourses must be preserved. ② Tree planting priority will be given to banks with no natural forests. As in the Mantasoa zone, the landslide potential is high in the southern part of the Tsiazompaniry zone. The percentage of forests must be increased, with tree-planting around the field. Planting on steep slopes must be avoided. With the displacement of the tanety to other areas after planting for 3 to 5 years, measures must be taken to prevent the extension of gully erosion in ravines due to drainage canals built around the tanety.

Forest conservation area

(1) Mantasoa zone

The forest conservation zone only represents around 30% of the Mantasoa zone. This is the western part of the lake (zone B) with pine forests for secondary residences. This vegetation is expected to help the conservation of the landscape. In the eastern shore (zone E), natural forests can still be found even if their surface area is very small (around 3%). They play an important role in soil and water conservation in the watershed to prevent outflow of soil. Vegetation in this zone includes Philippia shrubs which represent the biggest portion of the natural vegetation in the eastern shore Mantasoa. This small shrub is present in a thin layer in these areas (see Chapter II, 1-3 Soil properties in the target area), not adapted to farming and the industrial tree planting of eucalyptus. Consequently, in these Philippia zones, tree planting must be re-established by relying on nature with sufficient time for growth, to prevent forest fires.

(2) Tsiazompaniry zone

Natural forests in the southern part of the eastern shore of the lake (southern part of zone E) are the only important natural forests in the target zone. The watercourse flow from these forests into the lake is relatively stable even during the dry season. Even if the difference in height of the watershed and the watershed surface is high with respect to other zones, there is no soil degradation which may lead to landslides. We may therefore say that the southern part of the eastern Bank provides an important hydrological contribution to the lake. The southern end of the natural forest area constitutes a habitat for aquatic birds. Radical restrictive measures must therefore be taken such as the prohibition of cutting in the natural forests of these zones to ensure their conservation. The vast grasslands in this zone should be included

in the participatory watershed management project as a target area for ZODAFARB to promote massive tree planting.

5 Overall watershed management plan

The objective of the overall watershed development plan is established under the principal objective of achieving "a sound land use for the environment of the entire watershed." The importance of the relation between the villagers and the zone is variable in all watersheds. The management method varies depending on whether it is the villagers or the State who plays an essential role for the management of the watersheds. For a general watershed management plan, the region is divided into two areas as stated in "3" above; the area subject to participatory watershed management plan, and the forest preservation area. A general watershed management plan suitable for each area is to be made. The size of each land area is as shown in Table IV-2.

Table IV-2 Overall plan of watershed management

Unit: ha

Zone	Participatory watershed management area			Forest conservation zone			Total
	Mantasoa	Tsiazompaniry	Sub-total	Mantasoa	Tsiazompaniry	Sub-total	
A	514	4,304	4,818	0	0	0	4,818
B				1,461	0	1,461	1,461
C	1,772	4,755	6,527				6,527
D	3,208	17,850	21,058				21,058
E	1,158	5,570	6,728	1,180	2,525	3,705	10,433
Total	6,652	32,479	39,131	2,641	2,525	5,166	44,297

Note: Water surface excluded. * Participatory watershed management includes ZODAFARB target area of 2,330ha (1,158ha of Mantasoa and 1,172ha of Tsiazompaniry) which is eastern area of the lake managed by Ministry of Water and Forests.

For the participatory watershed management area, a watershed management plan centered on the villagers will be established. Zone E of the Tsiazompaniry zone includes the Ankazotelo village which was recently designated as a fokontany. As such, the plan was established by including this village. Villagers of this area have created their own living surrounding and carry out various activities for the conservation of the watersheds within the content of their production activities. Therefore, in this area, projects that will be able to be generalized based on the results of PSs is to be selected, and plans that will be able to be carried out by villagers is made.

The forest conservation zone is different from the participatory watershed management area, which includes zones B and E. A forest conservation plan will be and should be established for these areas by the Ministry of Water and Forests. Zone B is centered on secondary residences and will therefore be easy to conserve as a forest area. These zones include very few natural forests. The artificial forests principally have eucalyptus and pine trees where

birds and animals are rare. This zone will be covered by a landscape beautification program. Zone E is already managed by the Ministry of Water and Forests. Homes and farms of the villagers located elsewhere are very few, except in the Ankazotelo village. Since this situation includes very few cases, the Ministry of Water and Forests will have to take responsibility for these.

The forest management capacity of the Ministry of Water and Forests are limited. As such, ZODAFARB measures are introduced into areas manageable by the villagers from the topographical viewpoint. The villagers themselves must plan their own forest management system (basic approach). Forest management by the villagers seems to be effective. We consider that forest management jointed with resident management is effective approach. Then the participatory watershed management plan includes grasslands as target of ZODAFARB. Zone E of the Lake Mantasoa includes LAVAUDEN-V zones, with the expected transfer of land rights. Since tree planting is obligatory on slopes of more than 8% (angle of 3.5°), the biggest part of this zone must be planted with trees. A global forest management plan will be established by integrating this zone into the forest conservation zone. The scheme of the general watershed management plan is shown in Figure IV-2.

Figure IV-2 Framework of the overall watershed management

Total watershed management plan

Participatory watershed management plan

Area : 36,801ha
Main operator : Residents

Objective:
Continuity of development

Target area

Participatory watershed management area
Village type
I 340 households
II 200 households
III 1,180 households

Objectives of watershed management classified by zones

Improvement of land use methods

1. Improvement of land productivity (zone C)
2. Proper land use planning and pastureland management (zone D & E)

Contents of the plan

1. Contents of projects

A project plan shall be made for each type of village.
The plan contains eight kinds of projects in the following four fields. As projects to be covered by the plan and rates of interested households of the inhabitants differ according to village types, the contents of a project plan depend on the village type.

1) Agriculture
 * Planting of fruit trees
 * Compost production
2) Agroforestry
 * Hedging
 * Fodder production
3) Forestry
 * Production of young plants
 * Afforestation
 * ZODAFARB
4)Fishery
 * Fish farming in rice fields

2. Conduct of ZODAFARB
3. Activities for spreading
4. How to carry forward projects

In a plan for each village type, it will take five years to make a round of the area covered by the plan. It is aimed that each village will become independent by executing the plan for three years in total: one year for planning and the remaining two years for execution. Evaluation will be made after five years, and necessity of follow-up will be discussed.

Forest management plan

Area : 7,496ha

Main operator: Ministry of Water and Forest

Objective:
Preservation of natural environment

Securing water resources

Target area

Forest preservation area

Zone B 1,461ha

Zone E 6,035ha

Foundations of forest management classified by zones

Improvement of quality of natural environment

Creation and preservation of forests

Items to be executed for forest management

1. Issuance of timber-felling licenses with consideration given to natural environment
2. Prohibiting controlled burn in principle
3. Obligating licensees to renew their licenses after felling
4. Execution of environmental assessment of developments (other than agriculture) that will change topography.
5. Activities to encourage planting and culture of ornamental trees, taken by a local forestry office, rural commune and other parties in one united body

1. Stoppage of issuance of licenses for natural-tree felling
2. Prohibition of entering into a mountain area for a certain period
3. Stoppage of issuance of licenses for controlled burning
4. Execution of activities to enlighten residents
   Activities to enlighten residents about forest management are taken, includi requests for cooperation to local administrative organs, enlightenment activi through mass media, and requests for patrols to the police.
5. Promotion of participatory management plans for forests through ZODAFAI

After a certain period (about five years), the state of recovery of vegetation will be investigated and measures for subsequent management will be discussed.