# Monitoring of Desertification and Possibility for Agro-Farming-Forestry Development

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**Abstract**

The development of desertification is intense in Sahel region at the rim of Sahara Desert, giving various influence on the agriculture, cattle grazing and forestry as well as the regional society. This study has been carried out by Japan Agricultural Land Development Agency (JALDA) as a part of its Desertification Control Measures Verification Survey, in which we (1)implemented the monitoring of desertification at the typical urban area and rural area in the Sahel region where the desertification is advancing and (2) discussed the possibility agricultural/ grazing/forestry development at the village area at the vicinity of Niamey in Niger.

In monitoring of desertification, we used the multitemporal data of artificial satellite LANDSAT and timeserially identified the development of desertification from the changes of vegetation and land form observed at urban area and village area.

On the other hand, we discussed the possibillty for agro/grazing/forestry develoment by assuming the productivity and supporting soil fertility from the soil classfication based on the LANDSAT TM data.

## 1. Outline of the Study.

### 1.1 Outline of the study area.

The study area were the urban area around Niamey, the capital of Niger, and rural area around

Magou village located 50 km south-west from Niamey (Fig. 1). These areas are located under the severe climatic condition where annual precipitation is 600 - 700mm, while evapotranspiration is 1,900 - 2,000mm, and rain-fed agriculture and cattle grazing are carried out actively in these areas. The topography here is flat in general, and composed of three kinds of land form of plateau, gentle slope and wadis. The Niger River is running from north-west to south-east and Gorubi River which is a wadis running from west to east is flowing into the Niger River. The fertile soil is built up at the flood plain of wadis such as Gorubi river,and vegetables and fruit tress are grown at a part of them. In addition, gravels of weathered graite and unweathered rocks are exposed at the plateaus and gentle slope around them.

### 1.2 Study method

The study was implemented by the method shown below.

(1) Artifical satellite data:

The artificial satellite data used for the study is LANDSAT data of 6 different times from 1972 to 1992, which are respectively covered by one scene of PATH 195 -ROW 51 and SPOT of 1992.

(2) Monitoring of desertification

1) Vegetation change based on vegetaion index: Vegetation index is used when the plant activities are compared using the multi-temporal data of LANDSAT. The plant with higher activity has higher water content, and exhibits higher reflection property at near-infrared region, and withered plant has lower reflection property. Taking advantage of this principle, we calculated normalized vegetation index (NVI) and observed the changes of vegetation by constructing vegetation distribution map for each observatoin time.

2) Change of land use identified by image classification and image interpretation: In this stage, we made land cover classification using maximum likelihood method, added correction thereto by image interpretation, and identified the changes by constructing land use map of each observation time.

3) Clarification of development of desertification: We clarified the development of desertification basing on the changes in vegetation and land use identified by the above processes. As a result, we could clarify the decrease of vegetation at plateaus and wadis, soil erosion at plateaus and gentle slope, expansion of under area and appearance of green belt resulting for afforestation.

(3) Discussion on the possibillty for agro/grazing/forestry development

1) Basin area classification and selection of model areas: We classified the basin area bassed on the geographic maps of village area for agro/grazing/forestry development according to the mode of development.

2) Soil classification: The soil classification was made by interpreting the false color image compiled from the most recent LANDSAT TM data and taking into account the results of site survey.

3) Assumption of land productivity: We established the unit of land productivity for each soil classification from the statistic data and results of experimental farm, and assumed the

productivity of total area.

4) Trial calculation of supporting soil fertility: Basing on the above results and statistic data of Niger, we calculated the soil fertilty to support human and animal (cattle) population.

## 2. Monitoring of Desertification

As for the monitoring of desertification, we calculated the vegetation index from the LANDSAT data of 1972 - 1992. Clarified the change of vegetation area and erosion of land in detail through the classification and interpretation of images .

### 2.1 Desertification in the total study area

(1) Changes of vegetation

1) The density of vegetation varies largely from north to south in the study area. The vegetation is dense in general in the south, while the vegetation is sparse in the north excepting river side of wadis and green belt around the city of Niamey where dense vegetations are observed. Partially, the paddy fields along the Niger River are expressed as dense vegetation area.

2) The comparison of vegetation indices of different observation times shows clear declining tendency of vegetation as a whole during the period from 1972 to 1992. The vegetation which occupied about 60% of total study area decreased to 50% in 1984 and to approximately 20% in 1990.

3) The decline of vegetation started at the vicinity of Niamey and expanded to suburbs along with the lapse of time. This is due to the lumbering of firewood.

4) The decline of vegetation is more intense in the rims of plateau rather than in the plateau itself.

5) In the LANDSAT data of dry season, the representative vegetation millet is not identified as plant because all of them have been eaten by livestock and only the bases are left.

6) True grasses are dominant among the herbaceous plants and die away in dry season just like crops such as millet. The herbaceous plants are decresing due to the grazing of cattle.

(2) Erosion of soil

We verified the situation of soil erosion using the LANDSAT TM images of 1984 and 1989, The following tendency was observed at the plateaus located at the south-west of Niamey.

1) In the false color image of 1992, the surface of plateau is expressed in whitish color as a whole at the upper layer of plateau, and sandy soil of plateau is exposed to the surface. As a result, run-off of sandy soil is occourring at the banks of wadi rivers.

2) Sand and soil existing in wadi river are those which have run out from plateaus and gentle slope, which in some part have caused the closure of river-mouth.

### 2.2 Desertification at urban area (Fig.2)

(1) Decline of vegetation

1) As for the vegetation at the vicinity of Niamey, the tress have been lumbered as firewood, and shrubs have also decreased extremely at the plateaus and rim of plateaus located at the suburb of the city. According to the vegetation index, the vegetation which occupied 12% of total urban area in 1972 decreased to 9% in 1975, and to 6% in 1989 - 1990.

2) The demands for fuel wood in Niamey City amounts to 130,000 tons of firewood and 100,000 tons of charcoal every year, and about 500,000 stales (until of fuelwood equivalent to $m^3$) of fuelwood are lumbered and transported to the city.

(2) Expansion of city area

Intensive inflow of population is taking place from village area to city area in the study area, and the population of Niamey has more than doubled during 15 years from appoximately 240,000 in 1977 to appoximately 500,000 in 1992. According to the LANDSAT TM data, as a result, the city area expanded 3.6 times during 18 years from 14 $km^2$ in 1972 to 45$km^2$ in 1990.

(3) Greenbelt

Incerase of vegetation is observed at the green belt around Niamey, which is useful as wind brealing and sand arrestation of the city. The green belt was started from 1965 by continuously planting Niem and Eucalyotus, and it has expanded to 1,600 ha. around the city
area.

### 2.3 Desertification at village area (Fig.3)

Magou is a typical farming village located at about 50 km south-west of Niamey. JALDA established experimental farm along the Gorubi river which runs across Magou Village, and is implementing each kind of verification tests for the purpose of agriculture/village development which willbe beneficial for desertification control.

(1) Increase of bare land at gentle slope

Vegetation has rapidly decreased around the plateau due to lumbering of firewood and cattle grazing, and bed rock is exposing at many place because the surface soil was eroded by strong
precipitation of rain. Rain-fed agriculture of millet, etc. is carried out at the gentle slope with some fallow period, and there are some seasons when the gentle slope are covered with green. But the area of farm land tends to decrease along with the expansion of bare land.

(2) Flood plain along wadis

Fruit trees, etc. are planted at the flood plain along wadis, and Kabey (Mitragyna Inermis; botanical name = Rubialeae) distributes most widely. Here too, deciline of vegetation is observed partly due to lumbering.

(3) Decline of vegetation

According to vegetation index, vegetation occupied about 38% of Magou Village area in 1972 and 34% in 1975, which acutely decreased to 8% in 1984 and 7% in 1989. This decline is

considered to be due to lumbering of firewood. As Magou village is near to Niamey the shrubs around the plateau are widely used as firewood.

### 3. Discussion on the Possibility for Agro-Farming-Forsetry Development

#### 3.1 Present state of agriculture/grazing/forestry at village area.

As is clear from the monitoring of desertification, the advance of desertification at village area is mainly attributable to (1) increse of bare land due to overgrazing and over-cultivation and (2) decrease of vegetation due to lumbering of firewood. As a result, land productivity declined and farm lands were abandoned more widely, resulting in impoverishment of agriculture/grazing/forestry development at wadis, and the develoment is comparatively difficult in most cases because not only water resources but also personnel and physical resources are limited. The agriculture/village development at the rural area can be summarized as follows.

1) Chronical food shortage due reduction of water resources resulting from drought and aridity as well as to the deterioration of land fertility resulting from over-cultivation.

2) Shortage of forage and energy and develoment of soil erosion cause by the decrease of vegetation resulting from over-grazing and lumbering of firewood

3) Collapse of production base and living base of local residents (most of them are farmers) resulting from the shortage of food, forage and energy

4) Increase of refugees of farmers who lost the basis of production and livelihood

5) Staggering of national economy and increase of social anxiety

#### 3.2 Measures for agriculture/grazing/forestry

The following measures can be considered for the agricluture/grazing/forestry which take into account the deseritification control at the village areas.

(1) Farm land conservation measures

1) Since the precipitation force of rain is very strong, run-off of soil is plenty and soil layer is thin. As a result, the cultivate farm lands easily become bare land if land management is neglected. In order to cope with these situation, it is necessary to implement contour line farrowing agriculture to prevent the outflow of soil.

2) Since exposed laterite rock is conspicuous at plateau rim, it is exposed laterite rock is construction and weathering of these rocks by constructing water channels at the rim of plateau. This will be useful for preventing rapid outflow of plateau. This will be useful for preventing rapid outflow of water to gentle slope and also for preserving the water resources at the upper part of gentle slope . Furthermore, afforestation must be done at lower parts of plateau rim to reserve the water resources and secure the firewood.

(2) Measure for restoration of lost land

1) Production of sand and soil is restrained by piling up stones along the contour line at acute slope land at the lower part of plateau.

2) As for the outflow of sand and soil, on the other hands, acute production of sand and soil must be restrained by placing sand breaker such as sandbags at gullies and wadis.

(3) Measure for land use

1) Afforestation must be implemented on the plateau and at the acute slope land to reserve the water resource and secure the supply of firewood.

2) Effective land use must be implemented by establishing the system of rotation of millet, grassland and grazing land at the gentle slope and flood plain.

Here, we took the vicinity of representative village Magou as an example, and calculated the productivity and supporting soil fertility of land when the conservation measures mentioned above are actually implemented.

## 4. Diagnosis of desertification at Magou village area and planning of agriculture/grazing/forestry development

In this stage, we made diagnosis of desertification and drafted the agriculture/grazing/forestry development plan in an aim to control the desertification for Magou Village area where the " experimental farm " is located. In diagnosing the deseritification, we constructed (1) geomorphological classification map, (2)devastation state map and (3) land use map, and at the same time, implemented the land resource investigation for the total area of Magou Village, and finally, drafted (4) agriculture/grazing/forestry davelopment plan basing on these results.

### 4.1 Diagnosis of desertification

The main purpose of diagnosis of desertification is to grasp the present state and identify the cause of desertification at the study area for which the agrculture/grazing/forestry development plan is drafted. In case of present state diagnosis model and cause diagnosis model , it was necessary to investigate various factors such as present state of land use, geomorphological classification and devastation state using the artification satellite data.

(1) Geomorphological classification

We implemented geomorphological classification using the data of artificial satellite LANDSAT TM and SPOT in order to diagnose the desertification at Magou village. In greneral, the most idealistic way to classify the topography is to use the aerial photographs which have the highest resolution. However, the use of artificial satellite data is effective and more realistic in the areas such as surrent study area where it is difficult to make site survey and take new aerial photographs.

The geomorphology in Magou village and its vicinity is roughly classified into plateaus, acute cliffs, gentle slope, wadis and flood plain. Wadis and plateaus can be identification in more detail if the respective data.

2) Devastation state

As for the devastation state of Magou Village, the sandy/soil production and accumulation is conspicuous at wadi river. This is the interpretation results based on the vegetation index. As a result, the areas of soil erosion and sand accumulation have became clear at plateau rims around the wadis river which runs across the center of village.

(3) State of land use

As for the land use map of Magou Village, we decided to use the data which would make it possible to identify the millet fields, grassland, plateau and floodplain. We attempted to construct land use map using the data of LANDSAT TM and SPOT, but as a result, the vegetation index data of LANDSAT TM were most correctly coincident with actual state of the site. Generally,the vegetation index isued to identify the extent of vegetation vitality at the time(Fig.4).

It has become clear that 35% of total area of millet field and 23% is fallow land, and in total, virtually 58% is used as millet fields. The lands used for grazing are heabaceous plant/shrub area offallow land which amounts to 17% of the total area. in addition, a part of other fallow lands are used for grazing.

In the analysis in relation to geomorphological classification, gentle slope land occupies nearly 70% of the total area, and plateau/small hill and low land share about 15% respectively. Most of the gentle slope is millet field, fallow land and sparse forest.

### 4.2 Drafting of agriculture/grazing/forestry development plan

The agricultural/grazing/forestry develoment plan was compiled by calculating the balance of demand and supply at present land use and considering the measures for desertification control.

## 5. Conclusion

This study was carried out as a part of " Desertification Contorol Measures Verification Survey " at the vicinty of Niamey, and adjacent village area among Sahel region in order to (1) implement monitoring of desertification at under area and rural area and (2) to study the possibility of agriculture/grazing/forestry development at village area. As a result, we obtained the following conclusions.

(1) The city area is expanding at Niamey, the capital of Niger, due to the inflow of population from village area resulting from the develoment of deseritification.

(2) It was verified that a) conversion of farm land into bare land, b) deveopment of soil erosion and c) reduction of trees due to lumbering of firewood are conspicuous at the village area.

(3) In this study, we place the main focus on the agricultural/grazing/foresty development based on food and water measures. It is necessary in future to study the measures against damages.

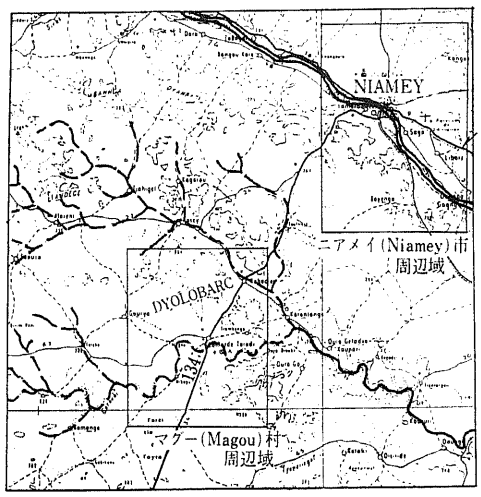


Fig.1. Study Area

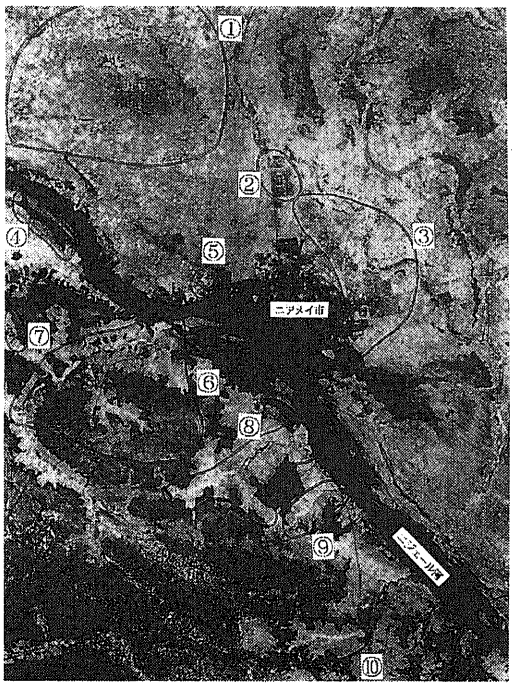


Fig.2. Niamey City


Fig.3. Magou Village

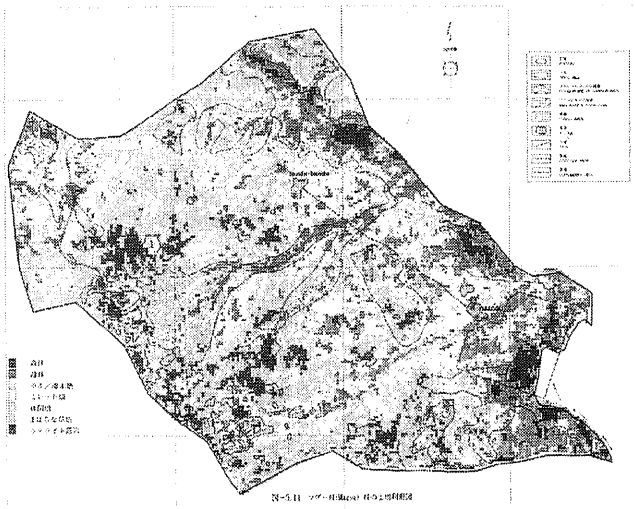

Fig.4. Land Use (Magou)