5-2-2 Present Land Use

The present land use of the study area is given in Figures 5-2-1 to 5-2-5 and tabulated as below:

Table 5-2-1 Present land use of the study areas

(Unit: ha)

Land use	M'Bahiakro	Dienzou	Yanmon	Eholie	Atofou
Upland Crop *1	160	20	70	100	80
Wetland Rice *2	440	0	0	0	0
Forest *3	0	120	260	145	230
Light forest/ Savane *4	160	15	140	505	190
Savane	1,310	230	15	135	0
Wetland	50	0	0	0	0
Village	10	5	15	15	10
Total	2,130	390	500	900	510

Remarks
*1: Including tree crops
*2: Including irrigated rice fields and lowland rice fields regardless of their current use.
*3: Including forêt dense, forêt claire and savane boisée
*4: Corresponding to savane arborée
*5: Including savane arbustive and savane herbeuse

The areas of upland crop fields are very conservative figures because many upland fields are invisible in the aerial photographs and not indicated on the topographic maps when they are scattered in the forest and light forest areas. Some of these hidden crop fields were identified through field survey and included in the figures of the upland crop mentioned in the above table. Though it was impossible to give correct areas of upland crop field, it can be roughly estimated that about 30% of the forest and light forest areas are currently under cultivation.

Wetland rice field, either irrigated perimeters or rainfed lowland rice fields are observed only in M'Bahiakro area. Although they are categorized as "Wetland Rice", less than half of them are actually used for cultivation. The rest is abandoned perimeters or under long fallow.

Savane is widely observed in M'Bahiakro, Yanmon and Eholie. It corresponds to unused alluvial plain and lower river terrace of the N'Zi river in M'Bahiakro, alluvial plain of the N'Zi's tributaries and lower slope of interfluves in Yanmon, and alluvial plain of the N'Zi river in Eholie.

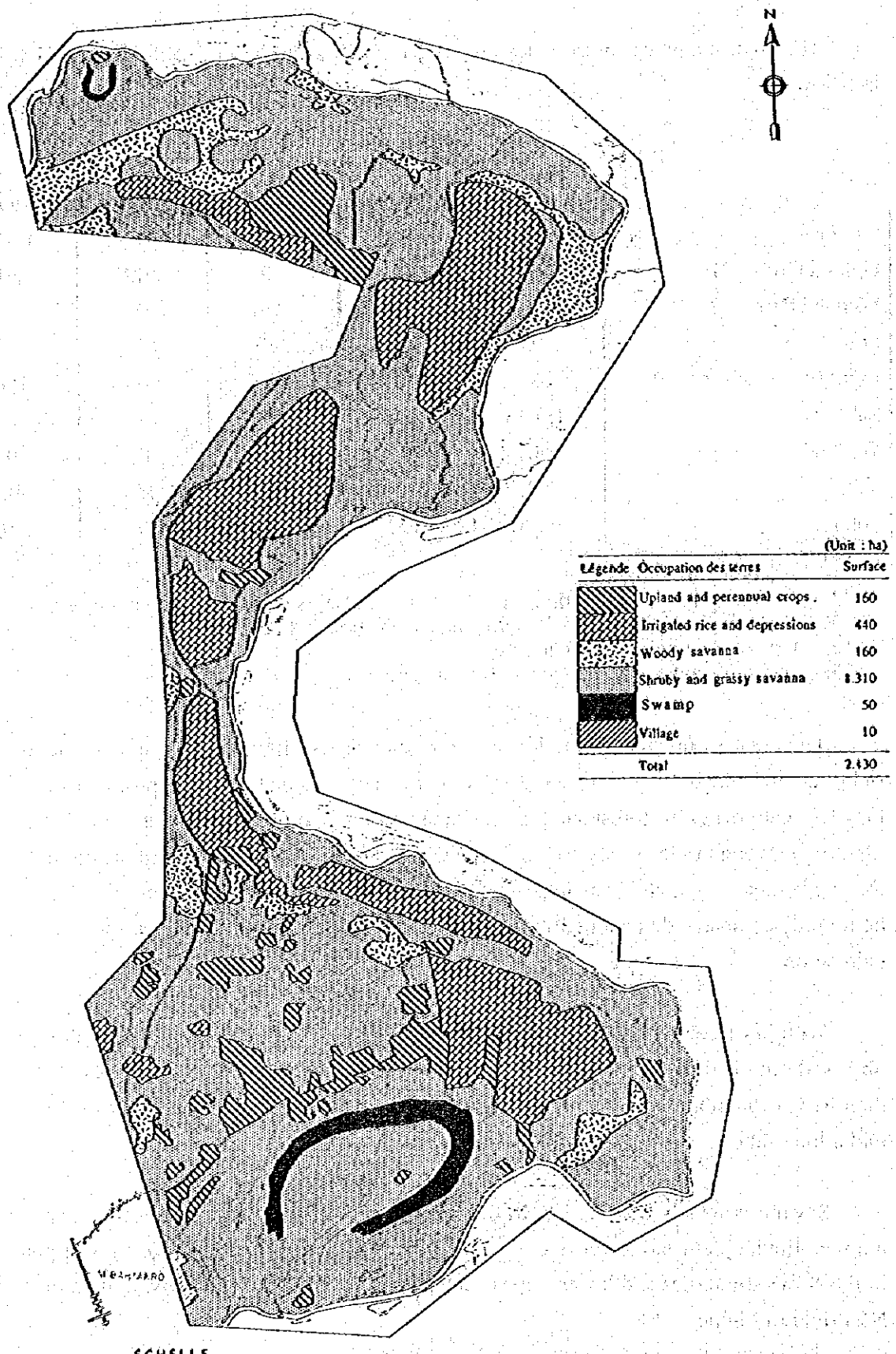


Figure 5-2-1 Land Use Map of M'Bahiakro Area

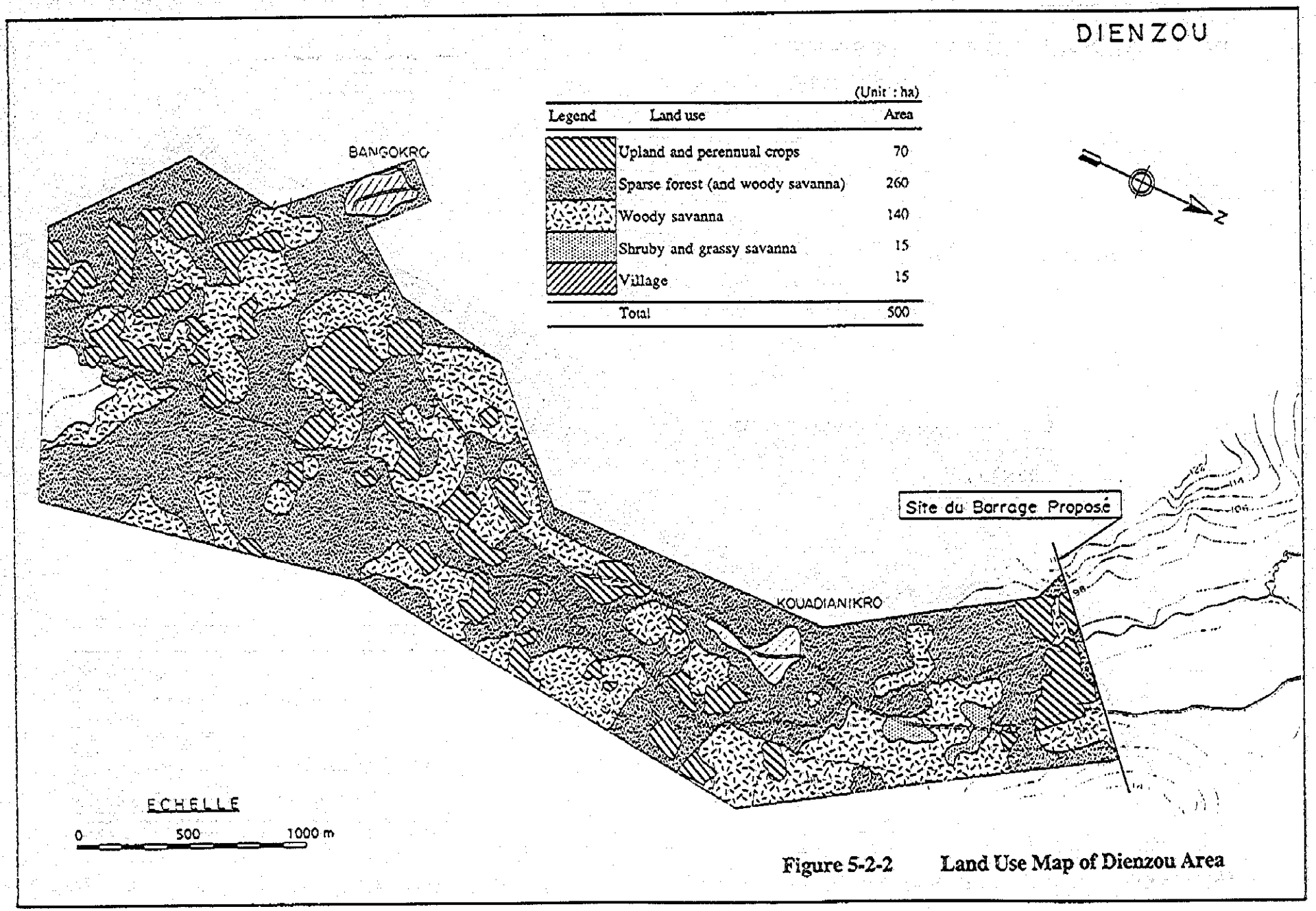


Figure 5-2-2 Land Use Map of Dienzou Area

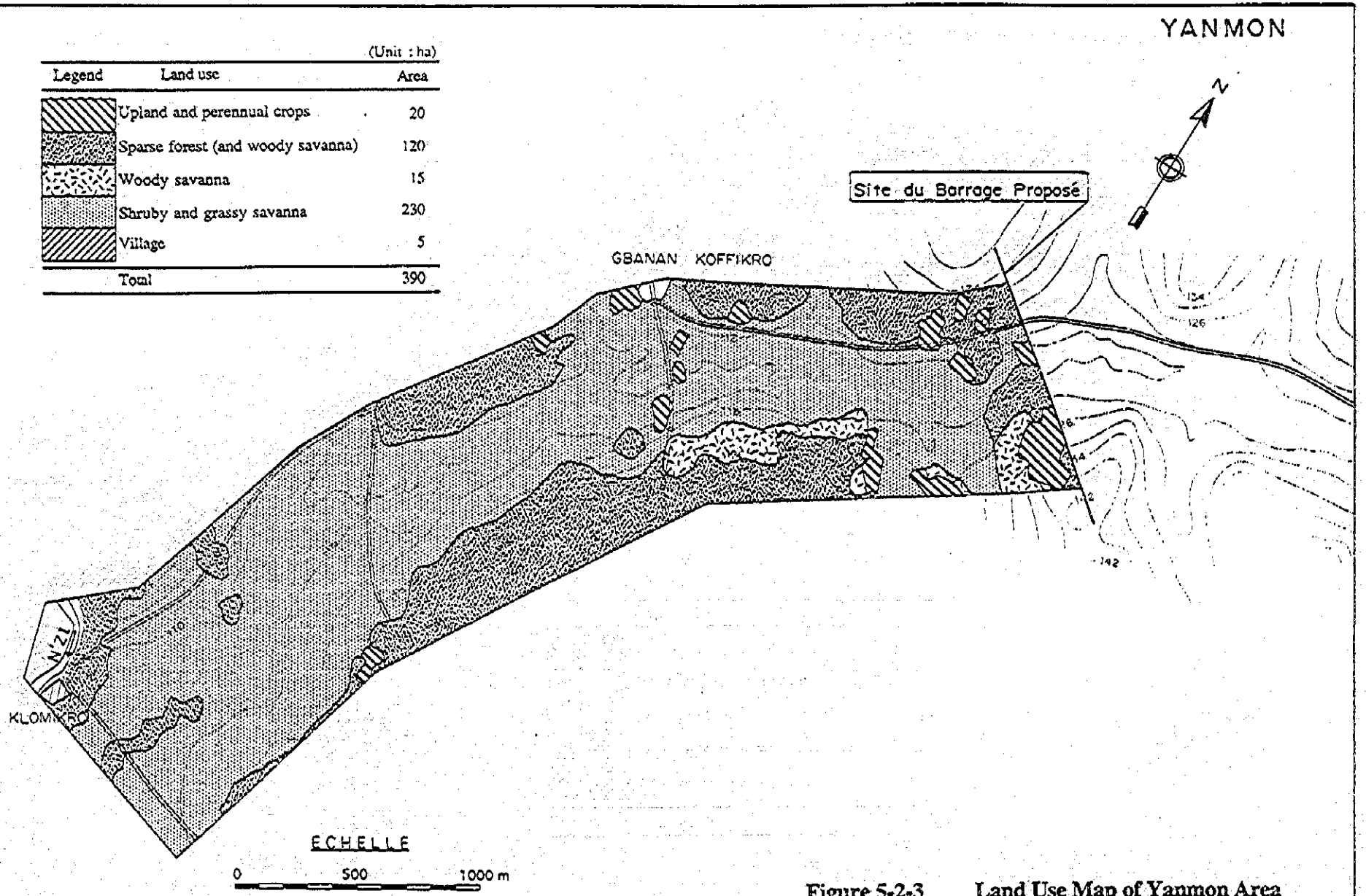


Figure 5-2-3 Land Use Map of Yanmon Area

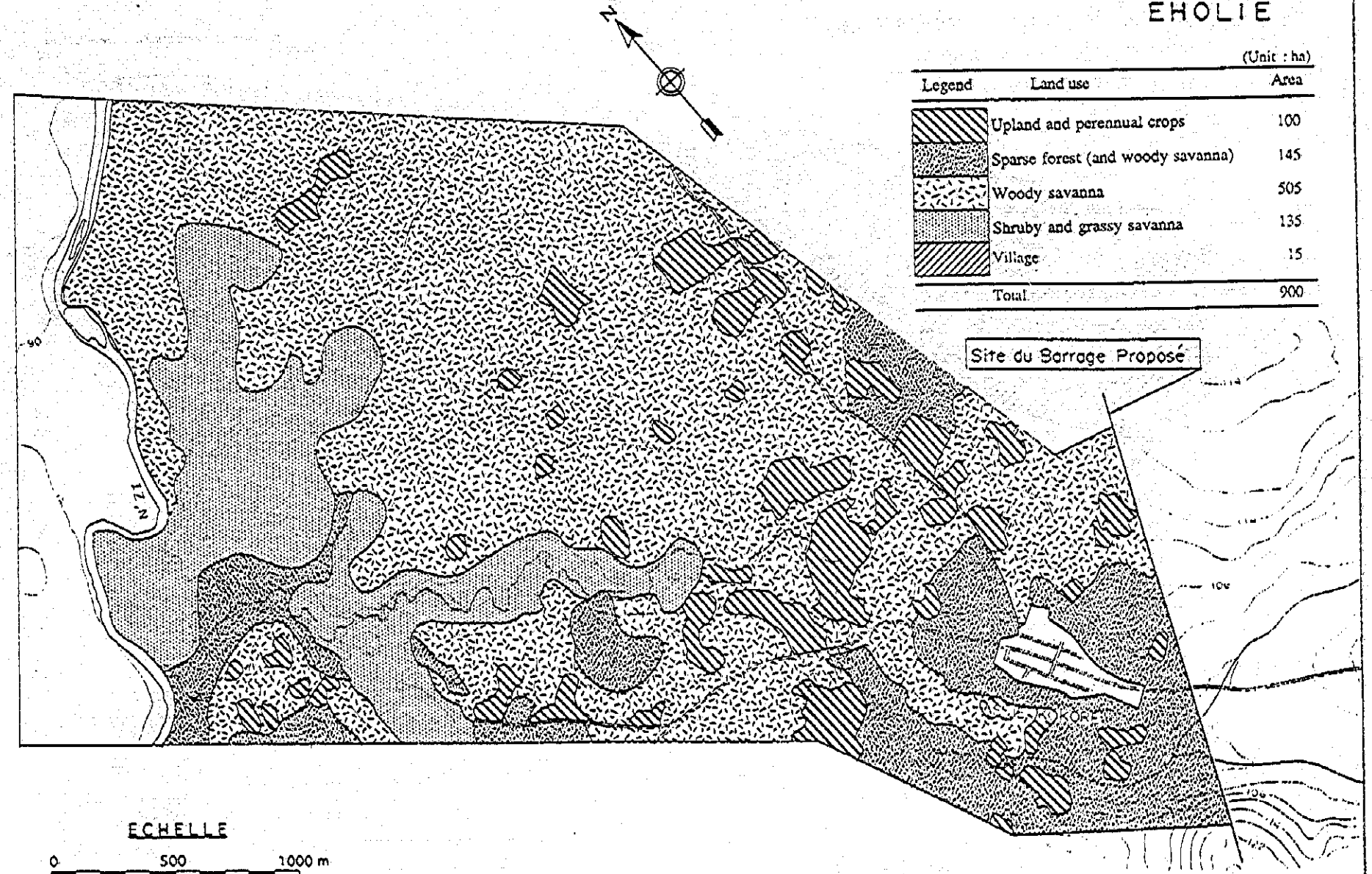


Figure 5-2-4 Land Use Map of Eholie Area

(Unit : ha)

Legend	Land use	Area
	Upland and perennual crops	80
	Sparse forest (and woody savanna)	230
	Woody savanna	190
	Village	10
	Total	510

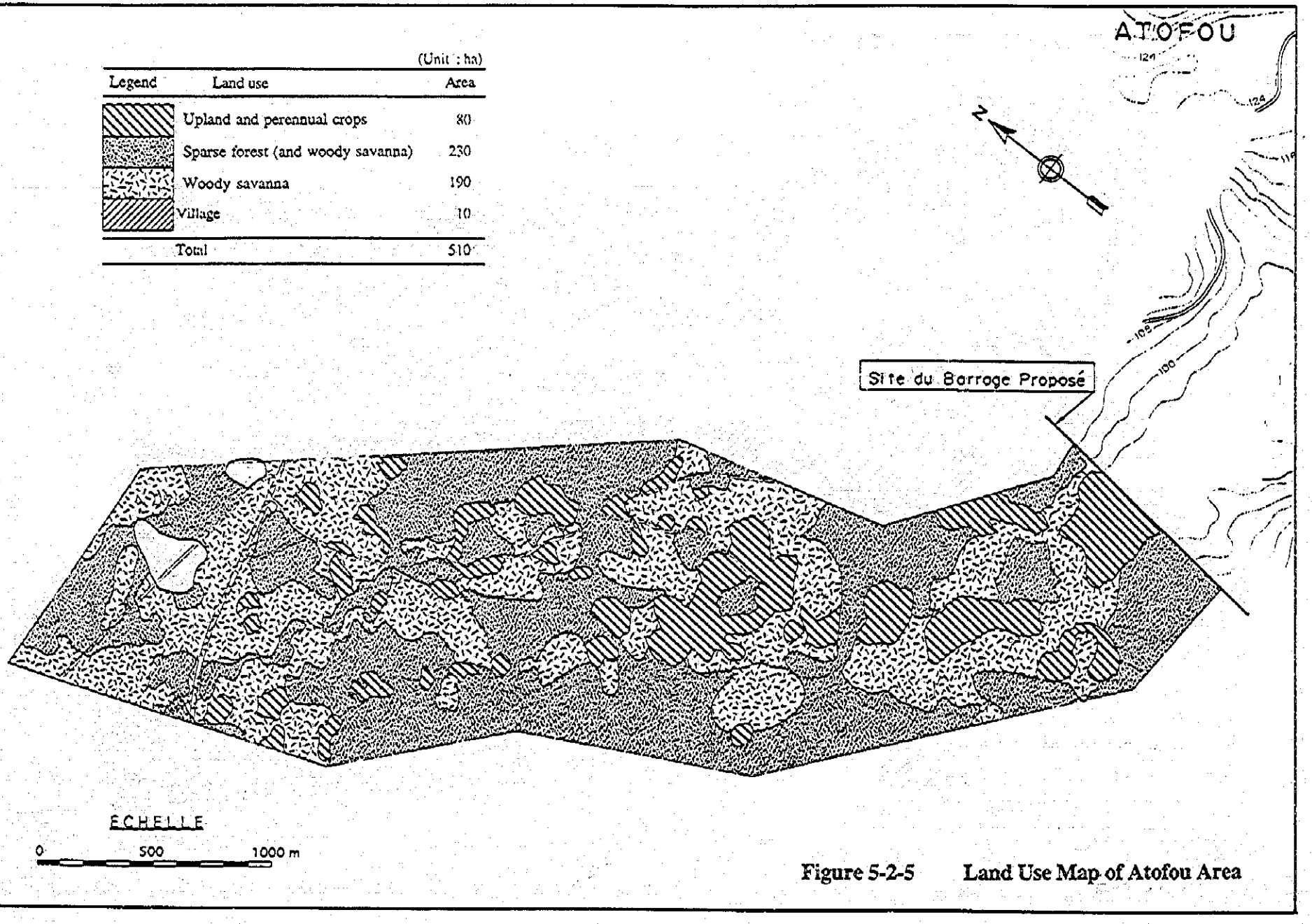


Figure 5-2-5 Land Use Map of Atofou Area

Present land use of the proposed reservoir area was studied based on the aerial photographs, topograhical maps scaled 1/5,000 and field reconnaissance. The result is given below:

Table 5-2-2 Present land use of the proposed reservoir area

(Unit: ha)

Items	Dienzou	Yanmon	Eholie	Atofou
Proposed reservoir area	122	82	155	269
Crop area	8	12	50	8

In Dienzou, Yanmon and Atofou, the crop areas are occupied by annual crops such as yam and maize, while plantain and cacao are dominant in Eholie.

5-2-3 Soils

In the study areas, six soil types (mapping units) are distinguished applying the soil association system. They are:

TYPE-1 Sols hydromorphe peu humifère à pseudogley de surface

This soil type widely extends over the rainfed lowland rice field located in depressed area and irrigated rice field in M'Bahiakro, regardless of their current usage. The texture is clay loam to clay [argile limono sableuse à argile] in topsoil and clay [argile à argile lourde] in subsoil.

TYPE-2 Association of Sols peu évolués d'apport alluvial hydromorphes and Sols hydromorphe peu humifère à pseudogley de surface

This soil type is observed in lower river terrace of the N'Zi river. The land of this soil type is flat and slightly higher than the land occupied by the TYPE-1 soils. The soil texture is slightly coarser than the TYPE-1 soils and varies loam to silty loam [limon sable argileux à lion] in the topsoil and silty clay loam to clay [limon argileux à argile] in the subsoil.

TYPE-3 Sols peu évolués d'apport alluvial hydromorphes

The soils are derived from recent alluvial deposits of the N'Zi river (Eholie) or the tributaries (Yanmon, Dienzou and Atofou) and extend on the flat lands along these rivers. In Eholie, the texture of the soils is silty clay to clay [argile limoneuse à argile] throughout the profile. The land has been often flooded in the rainy season. In other three sites, the soil texture is rather

coarser than that of Eholie site, loam to clay loam [limon sable argileux à argile limono-sableuse] in topsoil and clay loam to silty clay [argile limono sableuse à argile limoneuse] in subsoil.

TYPE-4 Sols peu évolués d'apport colluvial (texture grossiér en surface)

The soils extend in Eholie and Atofou. They are derived from colluvium which was transported by surface runoff and deposited on the lower slope of the interfluves. The texture of the soils is coarser than that of TYPE-3 soils. There is also a difference in soil texture between the two sites. In Eholie, the topsoil texture is sandy loam to loam [sable limoneuse à limon argileuse] and the subsoil texture silty loam to silty clay loam [limon sableuse à limon argileuse]. In Atofou, however, the texture is coarser; sandy loam [sable peu argileux] in topsoil and loam to silty loam [limon sable argileux à limon argileux] in subsoil.

TYPE-5 Association of Sols peu évolués d'apport colluvial modaux and Sols ferralitiques remaniés colluvionnés modaux

The soils extend in the middle and lower slope of interflues or plateau with plano-convex top. The soils are generally deep but sometimes contain much gravel in the subsoil. There is a difference in soil texture between M'Bahiakro and other four sites. In M'Bahiakro, the topsoil is loamy sand to loam [sable peu argileux à limon sable argileux], similar to the soils in other four sites, but the subsoil texture is finer and shows great variation, ranging from loamy sand to clay [sable argileux à argile]. The texture of the soils in other four sites is sand to loam [sable à limon sable argileux] in topsoil and loamy sand to loam [sable peu argileux à limon sable argileux] in subsoil.

TYPE-6 Association of Sols ferralitiques remaniés modaux, remaniés ajeunis and remaniés indurés

This type of soils extends on the middle and upper slope of interfluves, where slope is steep, and on the top of plateau. The soils are strongly weathered reddish soils. The soils are loamy sand to sandy clay in texture but often contain many gravel particularly in the subsoil. Laterite shell is sometimes underlay in shallow depth.

Areas of each soil type in the study area are given as follows:

Table 5-2-3 Soils in the study area

(Unit: ha)

Soil Type	M'Bahiakro	Dienzou	Yanmon	Eholie	Atofou
TYPE-1	980	0	0	0	0
TYPE-2	730	0	0	0	0
TYPE-3	0	100	65	255	160
TYPE-4	0	0	0	275	15
TYPE-5	220	275	200	265	205
TYPE-6	145	110	120	90	120
(Wetlands)	50	0	0	0	0
(Village)	5	15	5	15	10
Total	2,130	500	390	900	510

Soils maps of the five study areas are presented in Figures 5-2-6 to 5-2-10.

5-2-4 Land Suitability

The lands of each soil type were assessed in terms of their potential suitability for irrigated rice cultivation based on the soil texture, particularly that of subsoil, soil depth, slope and land form, and risk of flood hazard. The lands are classified into four classes as follow:

Class 1: Highly suitable
There are no limitations that will reduce crop yields or increase recurrent costs for the production.

Class 2: Moderately suitable
There are moderately severe limitation likely to reduce crop yield and/or increase recurrent costs for the crop production.

Class 3: Marginally suitable
There are limitations which in aggregate are sufficiently severe to reduce crop yield and/or increase production cost.

Class 4: Unsuitable
The land has very severe limitation which may be surmountable in time, but cannot be corrected with existing knowledge at currently acceptable cost, and is precluded from sustained use of the land in the given manner.

The area by each classes are given below:

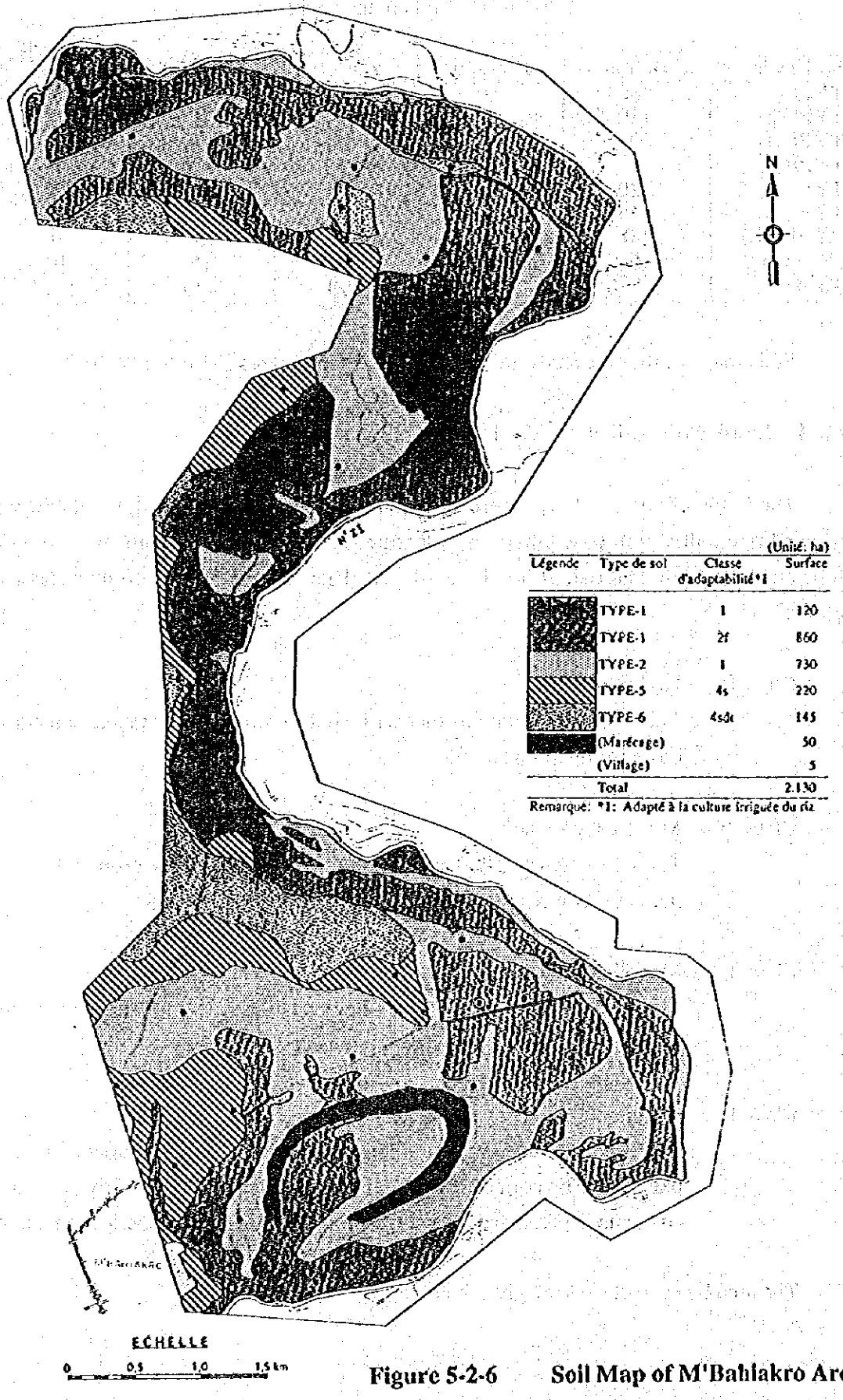
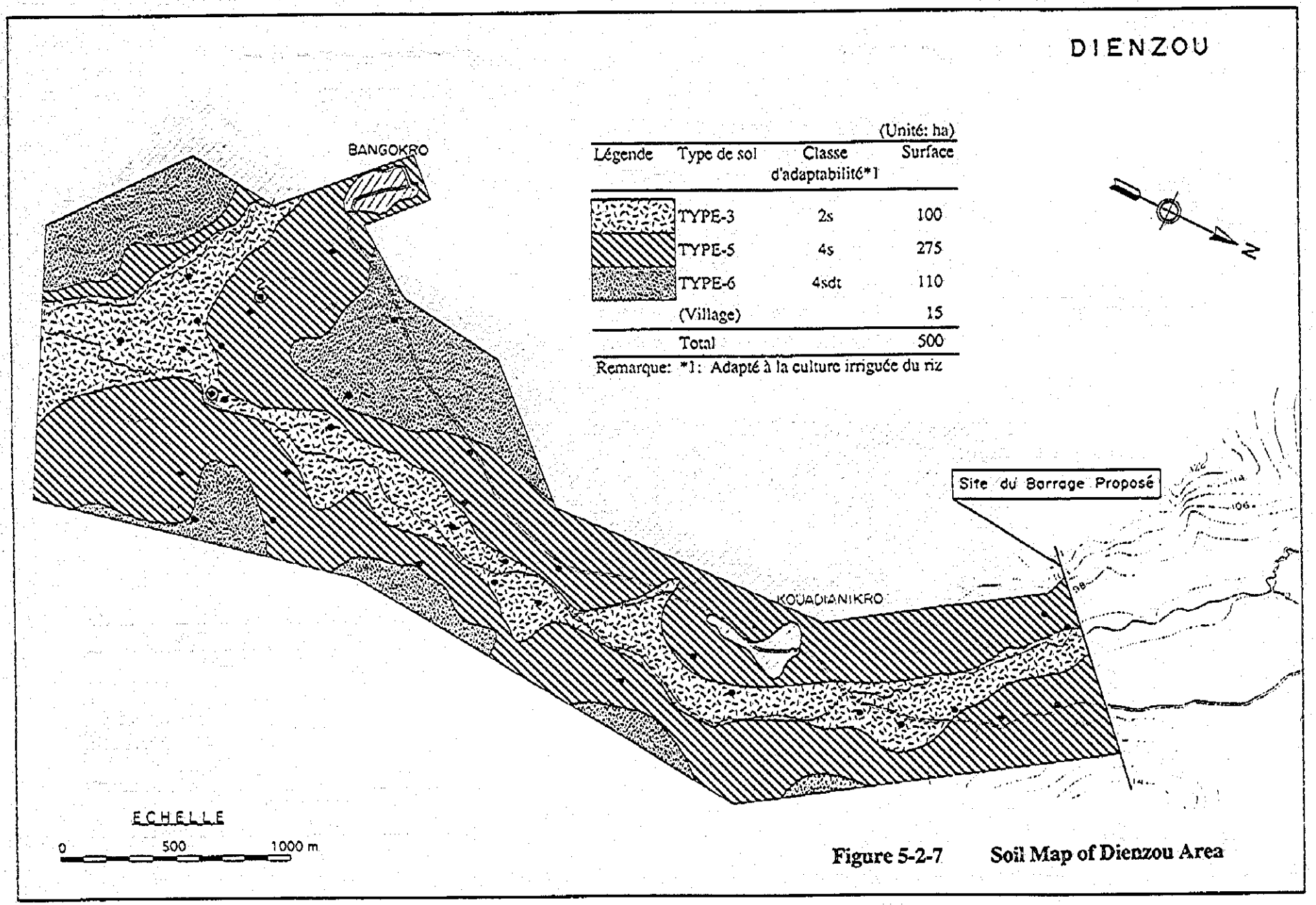


Figure 5-2-6 Soil Map of M'Bahiakro Area



(Unité: ha)

Légende	Type de sol	Classe d'adaptabilité*1	Surface
	TYPE-3	2s	100
	TYPE-5	4s	275
	TYPE-6	4sdt	110
	(Village)		15
	Total		500

Remarque: *1: Adapté à la culture irriguée du riz

Figure 5-2-7 Soil Map of Dienzou Area

(Unité: ha)

Légende	Type de sol	Classe d'adaptabilité*1	Surface
	TYPE-3	2s	65
	TYPE-5	4s	200
	TYPE-6	4sdt	120
	(Village)		5
	Total		390

Remarque: *1: Adapté à la culture irriguée du riz

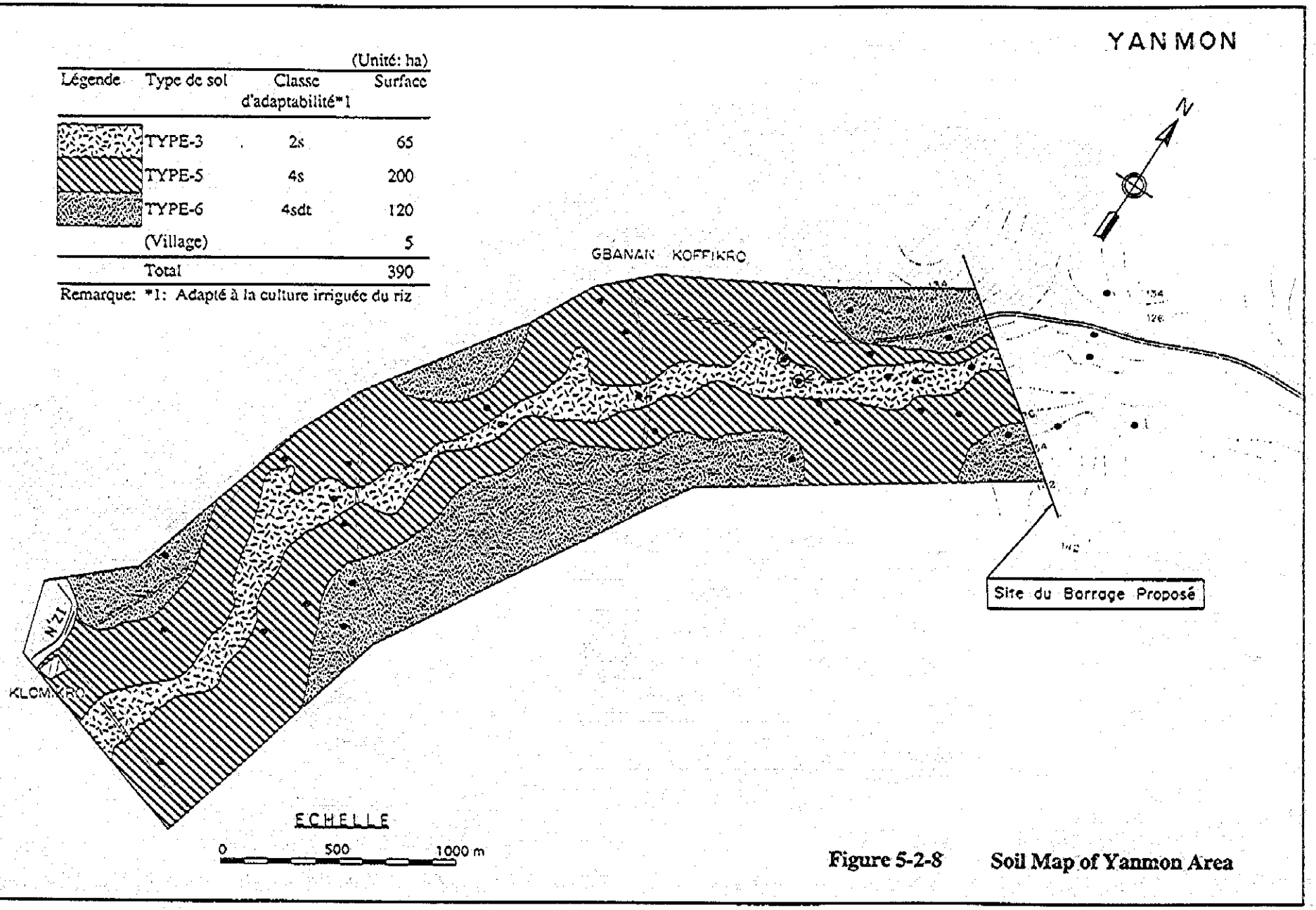


Figure 5-2-8 Soil Map of Yanmon Area

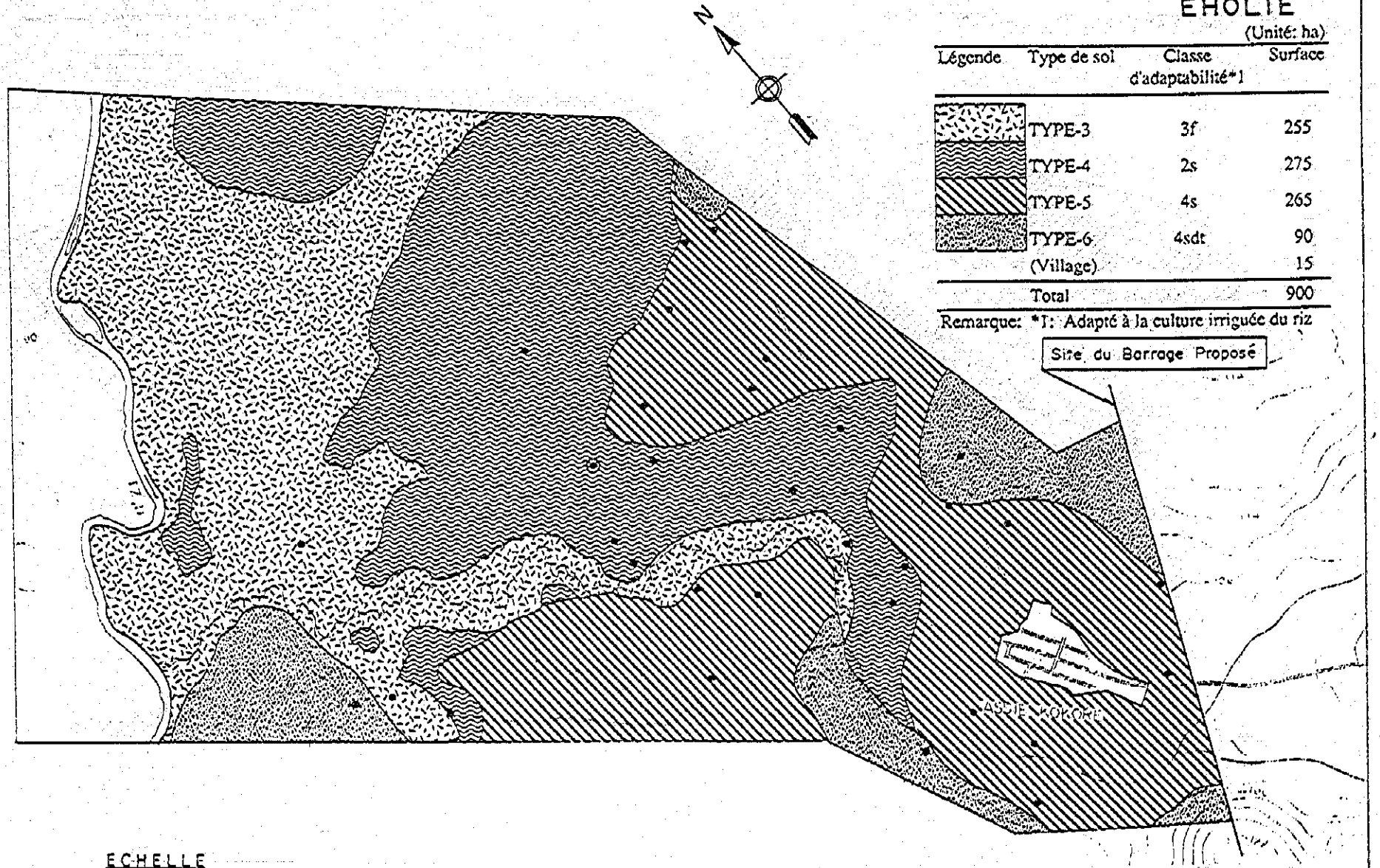


Figure 5-2-9 Soil Map of Eholie Area

(Unité: ha)

Légende	Type de sol	Classe d'adaptabilité*1	Surface
	TYPE-3	2s	160
	TYPE-4	3s	15
	TYPE-5	4s	205
	TYPE-6	4sdt	120
	(Village)		10
	Total		510

Remarque: *1: Adapté à la culture irriguée du riz

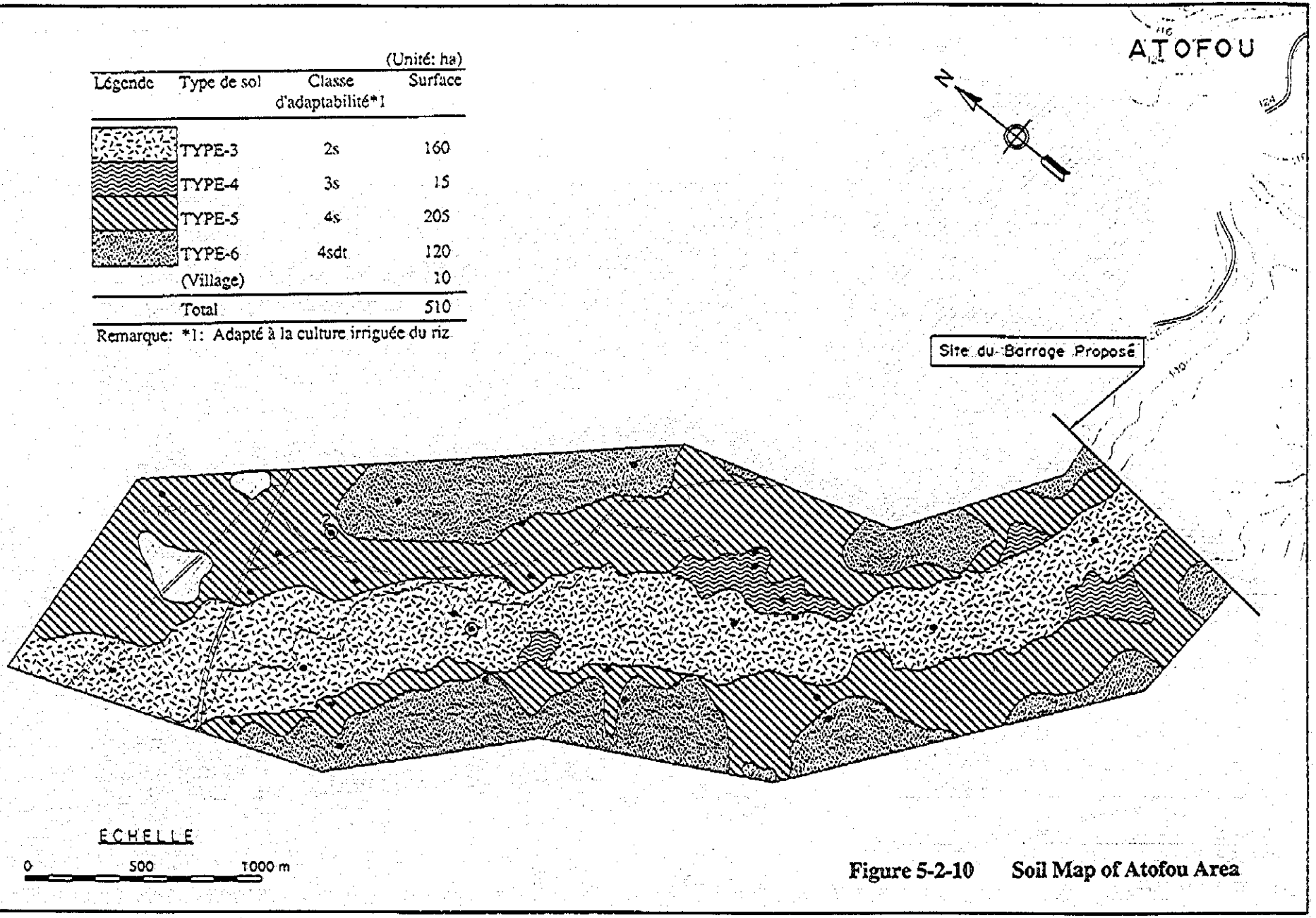


Figure 5-2-10 Soil Map of Atofou Area

Table 5-2-4 Area by land suitability classes

(Unit: ha)

Suitability classes	M'Bahiakro	Yamnon	Dienzou	Eholie	Atofou
1	850	0	0	0	0
2	860	55	100	275	120
3	0	0	0	255	10
4	365	330	385	355	250
Total *	2,075	385	485	885	380

*: Excluding the area of wetland and village

With regard to the land suitability for upland crop cultivation under irrigation, virtually the lands of all soil types are judged to be suitable for this type of use if irrigation is practiced using watering cans, not by surface gravity irrigation.

5-3 Irrigation & Drainage Development Plan

5-3-1 M'Bahiakro Area

(1) Topography and Geology

As mentioned in Paragraph 5-2-1, the M'Bahiakro area is a paddy field zone reclaimed by developing the alluvial plain and the lower terrace of the right bank of the N'Zi River. According to the 1/1,000,000 geological map, the foundation of the M'Bahiakro area belongs to B_F (Flyschs Éburnéens), however outcrop of the bed rock is not found. The surface soil texture is composed of silt and clay. The cross section of the N'Zi River at the project area of M'Bahiakro has the river bed of some 30 m of width, 50 - 60 m of the riparian width and some 7 m of the riparian height. According to the hearing survey from the farmers, the paddy field near the N'Zi River are inundated nearly every 5 years. The probable discharges of exceedance at M'Bahiakro gauging point are as follows;

Probable discharge at M'Bahiakro gauging point

Return period (years)	1000	100	50	30	10
Discharge (m^3/sec)	1039	757	672	610	470

(2) Present Condition

The project area is composed of 7 blocks spread out on the right bank of the N'Zi River, namely No.1 - 5 block, No.5 extension block and Diaby block. The project excluding No.5 extension blocks was originally carried out as a rice culture project by Société de Développement du Riz (SODERIZ) in 1970, and then No.5 extension block was developed in addition to those in 1986. The 7 blocks were planned to be irrigated with lifted-up water from the N'Zi River by movable type diesel engine pumps of 200 x 200 mm installed at each block. However, the pump of No.1 block was removed several years ago, and the pumps of No.3, No.4 and No.5 block are not operated on account of engine trouble in 1994. In addition to the fact that the pumping stations are quite superannuated, the operation cost is getting higher on account of both the big water level fluctuation and absolute shortage of the discharge of the N'Zi River when irrigated for dry season.

(3) Objective

The objective of the project is to stabilize the farmers' farming management by renewing the superannuated pumping facilities and assuring absolute volume of irrigation water to introduce two cycles paddy per year. For this objective, 1 low dam and 2 pumping stations and pipeline system of 5,240 m are constructed, and also the paddy field is readjusted together with the rehabilitation of the existing irrigation and drainage canals.

(4) Project Area

The proposed irrigation development area is 453 ha in total. The breakdown is as follows;

unit : ha

	No.1	No.2	No.3	No.4	No.5	No.5 ext.	Diaby	Total
Proposed Development Area	106.8	83.9	42.3	54.9	35.8	73.3	56.0	453.0
Proposed Net Irrigation Development Area	96.9	77.7	37.5	47.7	30.8	47.0	47.3	384.9
Existing Paddy Field Area	106.8	83.9	42.3	54.9	35.8	52.3	56.0	432.0
Existing Upland Area						21.0		21.0

(5) Selection of Irrigation Zone

The above-mentioned 453 ha of the proposed development area is divided in 2 zones so that one pumping irrigation system can be 250 ha or less taking into consideration

smooth management of the operation & maintenance organisation and smooth water management such as equal distribution of irrigation water.

No.1 Zone

No.1 Block, No.2 Block, No.3 Block

- Proposed Development Area : 233.0 ha
- Proposed Net Irrigation Development Area : 212.1 ha

No.2 Zone

No.4 Block, No.5 Block, No.5 Block Extension, Diaby Block

- Proposed Development Area : 220.0 ha
- Proposed Net Irrigation Development Area : 172.8 ha

(6) Size of Structures

The full reservoir capacity is planned to be 2,760,000m³, which can satisfy the water requirement responding to the five years return period drought (nearly equivalent to the fourth drought year from 1973 ~ 1992) based on the water balance analysis of 20 years data from 1973 ~ 1992.

The size of irrigation facilities for intake and delivery are determined so that 1.55 lit/sec/ha as design unit water requirement, representing 24 hour successive pumping operation at peak stage as detailed in Paragraph 4-3-3 of Chapter 4, can be conveyed. Taking into consideration ease of the operation & maintenance and hazard dispersion in case of break down, each zone is planned to have respective pumping station.

5-3-2 Areas of Dienzou, Yanmon, Eholié and Atofou

(1) Topography and Geology

(a) Dienzou Area

The proposed dam site is located around 3 km downstream along the Dienzou river, which is a tributary of the N'Zi River, to the south east from Boore Akpokro village located along the national road. The elevation of the river bed at the dam site is 93 m, and the specific elevation of the reservoir bed from the river bed to the hill is between 10 m and 20 m. According to the geological map, the geological feature of the area belongs to Bp (Flyschs Éburnéens), however no outcrop is found on either the river bed or the abutment. The river bed at the dam site is widely covered with alluvium which is composed of silt and

clay. The fine gravel appears at around 50 cm below the ground level where the aquifer exists. According to the geological map, no fault affecting the design of the dam is found, and no land sliding topography is also found at the adjacent area of the reservoir. The ground water level is some 50 cm below the ground level. An earth dam having some 15 m of height can possibly be constructed.

(b) Yanmon Dam

The proposed dam site is located around 4.7 km upstream along the Yanmon river, which is a left bank tributary of the N'Zi River, to the north east from Klomikro village, of which elevation is 106.8 m, located along the N'zi river. The elevation of the river bed at the dam site is 118 m, and the specific elevation of the reservoir bed from the river bed to the hill is around 40 m. According to the geological map, the geological feature of the area belongs to B_F (Flyschs Éburnéens), however no outcrop is found on either the river bed or the abutment. The dam site is hardly covered with alluvium but widely with diluvium. Crystalline schist is outcropped along the right bank water side at Klomikro village, and the strike is N50° E and the dip is 30° E. According to the geological map, no fault affecting the design of the dam is found, and no land sliding topography is also found at the adjacent area of the reservoir. An earth dam having some 17 m of height can possibly be constructed from the viewpoints of the bearing capacity and the imperviousness of the foundation.

(c) Eholie Dam

The dam site is located in Assie Kokore village, which is located around 5.2 km upstream along Eholié river from the confluence with the N'Zi River. The elevation of the river bed at the dam site is 97 m, and the specific elevation of the reservoir bed from the river bed to the hill is around 20 m. According to the geological map, the geological feature of the area belongs to B_F (Flyschs Éburnéens), however no outcrop is found on either the river bed or the abutment. The reservoir bed is widely covered with diluvium, and non-bedding hard laterite is partially found from the elevation of around 100 m up at the right bank abutment of the dam. Several vertical holes having the diameter of some 0.8 m said for gold mine scatter in this hard laterite zone. According to the geological map, no fault affecting the design of the dam is found, and no land sliding topography is also found at adjacent area of the reservoir. An earth dam having some 17 m of height can possibly be constructed.

(d) Atofou Dam

The dam site is located around 4.5 km upstream along Atofou river, which is a left

bank tributary of the N'zi river, from N'drikro village located along the national road. The elevation of the river bed at the dam site is 93.5 m, and the specific elevation of the reservoir bed from the river bed to the hill is between 10 m and 30 m. According to the geological map, the geological feature of the area belongs to Bf (Flyschs Éburnéens), however no outcrop is found on either the river bed or the abutment. The reservoir bed is widely covered with alluvium, and the dam having the high storage efficiency can be expected. According to the geological map, no fault affecting the design of the dam is found, and no land sliding topography is also found at adjacent area of the reservoir. An earth dam having some 17 m of height can possibly be constructed.

(2) Objective

The objective of the project is to stabilise the farmers' farming management by newly introducing an irrigation system for paddy and upland crops. Which this consideration in mind, a dam and some paddy fields with gravity irrigation and drainage system will be newly constructed together with the access and on-farm roads and also the river training. Some field lots are planned as fish ponds. Rain-fed cropland is planned at the end zone of the irrigation development area.

(3) Project Area

The development area is determined taking into consideration both results of the soil & topographic suitability study and the water balance analysis. The determined areas are as follows;

Proposed development area

unit : ha

	Dienzou	Yanmon	Eholié	Atofou	Total
Proposed Development Area	110	80	130	200	520
Proposed Gross Irrigation Development Area	90	65	105	190	450
Proposed Net Irrigation Development Area	78	56	91	165	390
Rain-fed Area	20	15	25	10	70

The development areas are planned to be selected from the downstream neighbouring areas of the proposed dam sites to mitigate the construction costs.

(4) Size of Structures

The effective reservoir capacity is planned to be the maximum accumulated required storage volume based on the water balance analysis of 20 years data from 1973 ~ 1992 considering extremely unstable river run-off to be utilized.

The size of irrigation facilities for intake and delivery are determined so that 2.07 lit/sec/ha as design unit water requirement, representing 18 hours operation at peak stage as detailed in Paragraph 4-3-3 of Chapter 4, can be conveyed.

5-4 Rural Infrastructure

5-4-1 Basic Concept

The basic concept for planning of rural infrastructure for the develoment priority area is the same as mentioned in the section "4-4 Rural Infrastructure" of the Master Plan which takes up improvement of roads and village water supply as components.

5-4-2 Improvement of Rural Roads

According to the field observation, the present situation of roads connecting related villages with the trunk roads and proposed farm lands is shown in Table 5-4-1.

Most of feeder roads with laterite gravel pavement, to which maintenance works (grading, etc.) are applied two or three times a year, are found to keep "good" or "fairly good" practicability. Accordingly, among roads given in Table 5-4-1, those of "not so good" or "bad" practicability and those due to be submerged by the planned reservoirs are planned to be improved or replaced, so as to respond to general traffic and increased transportation volume caused by the agricultural development. In addition, some new roads are planned to be constructed to connect related villages with planned farm lands. The road improvement plan is shown in Table 5-4-2.

Table 5-4-1 Actual condition of access roads (1/2)

Sites & Roads	Distance (km)	Width (m)	Coating	Practicability	Remarks
M'BAHIAKRO					
M'Bahiakro Town-Kloufikro	2.3	6.5	Gravel	Good	
Kloufikro-Farm 1	5.5	3.0-3.5	Gravel	Not so good	1 Culvert
M'Bahiakro Town-Farm 5	1.0	3.0	No Coating	Poor	1 Culvert
DIENZOU					
Trunk Road (Boore Akpokro) - Kouadianikro	4.6	3.5	No Coating	Poor	2 Culverts
Trunk Road - Junction	1.9	7.5	Gravel	Good	
Junction-Bangokro-Kouadianikro	6.1	3.5	No Coating	Fair	4 Culverts
YANMON					
Trunk Road-Abongnikro-Gbanan Koffikro	11.2	6.5	Gravel	Fair	
Abongnikro-Klomikro	2.7	4.0	No Coating	Fair	1 Culvert
Gbanan Koffikro-Siedoukro	0.5	3.5	No Coating	Not so good	

Note: The remarks in the table refer to the number of culverts that are necessary to maintain the roads practicable even in case of rain.

Table 5-4-1 Actual condition of access roads (2/2)

Sites & Roads	Distance (km)	Width (m)	Coating	Practicability	Remarks
EHOLIE					
Trunk Road (Fronobo)-Aounienfoutou	8.5	3.5-5.0	Gravel	Fair	
Aounienfoutou-Assie Kokore	7.5	3.0-4.0	Partial	Not so good	1 Culvert
Assie Kokore-Assie Koyekro	2.1	5.0	Gravel	Fair	
Assie Koyekro-Assie Koumassi	1.6	4.5	Gravel	Fair	
Assie Koumassi-Trunk Road(Banabo)	12.0	5.5	Gravel	Fair	
ATOFOU					
Main Road(Ndrikro)-Planned Farm	2.7	3.5	No Coating	Poor	2 Culverts
Trunk Road-Kouakro	5.3	6.5	Gravel	Fair	

Note: The remarks in the table refer to the number of culverts that are necessary to maintain the roads practicable even in case of rain.

Tableau 5-4-2 Road improvement plan

Roads	Length (km)					Nber of Culverts
	New		Actual		Total	
M'Bahiakro		1.0		3.1	4.1	1
Kloufikro-Farm 1	A	1.0	B	1.0	2.0	
M'Bahiakro-Farm 5		-	A	2.1	2.1	1
Dienzou		5.4		4.5	9.9	4
Trunk Road (Boore Akpokro)-Kouadianikro	A	5.4		-	5.4	2
Junction-Bangokro-Kouadianikro		-	B	4.5	4.5	2
Yamnon		3.8		2.2	6.0	2
Farm- Upstream	A	3.8		-	3.8	1
Abongnikro-Klomikro		-	B	2.2	2.2	1
Eholie		3.8		1.1	4.9	1
Assie Koyekro - Assie Koumassi - Assie Kokore - Farm	A	3.8	B	1.1	4.9	1
Atofou		4.0		-	4.0	-
Kouakro-Farm	A	4.0		-	4.0	-
Total		18.0		10.9	28.9	8

Note : Remarque: Priority; A: High B: Low

5-4-3 Village Water Supply

In villages related to the development priority area, water for drinking and other living uses is supplied from wells equipped with a manual pump, except the case in Assie Koumassi equipped with a well and an electric motor pump driven by a diesel engine generator. In many cases, water for living uses other than drinking is supplementarily taken from streams or ponds. According to the observation and collected data from METT, the present situation of domestic water supply in related villages is shown in the Table 5-4-3.

Installation of additional wells with a manual pump is planned as shown in Table 5-4-3 to satisfy the criteria mentioned in the section "4-4 (2)".

Tableau 5-4-3 Plan of village water supply

Sites and Villages	Population	Existing Wells	Wells to be replaced	Existing Pumps	Needs
M'BAHIAKRO					
Akrifoukro	224	1		1	_
Ouakoukro	157	1		1	_
Abokro	1074	2		2	1
Ndjolekro	906	1		1	1
Gbangbo					
Kouassikro	1853	1		1	1
Dangou	2201	4		4	_
DIENZOU					
Kouadianikro	365	2	_	2	_
Boore Akpokro	692	2	_	2	1
Boore Ettienkro	584	2	1	1	1
Bangokro	774	3	_	3	_
YANMON					
Gbanan Koffikro	228	1	1(-)	1	1
Abongnikro	292	1	_	1	_
klomikro	108	1	_	1	_
EHOLIE					
Assie kokore	1574	3	_	3	1
Assie Koyekro	625	1	1	1	2
Assie Koumassi	3579	2	_	2	_
ATOFOU					
Ndrikro	539	2	_	2	_
Kouakro	1271	2	1	2	2
Fronobo	1368	2	1	2	2
Total		34	5	33	13

Remark:
1) The data in this table have been provided by "l'Antenne Régionale de Yamoussoukro, Hydraulique Villageoise, Direction de l'Eau, Ministère de l'Equipement, des Transports et des Télécommunications."
2) Concerning Gbangbo Kouassikro, the needs are 3 according to the criteria, but the data of "Direction de l'Eau" mention only 1 need.
3) Concerning Gbanan Koffikro, the well needs to be replaced even though this is not referred to in the data of "Direction del'Eau". During our field study, we observe that the well has dried out
4) One of the two pumps at Assie Koumassi is an electro pump. It is managed by SODECI and supplies enough water.

5-5 Agricultural and Animal Production

5-5-1 Present Situation

(1) M'Bahiakro Area

The perimeter of M'Bahiakro, created by the SODERIZ (Société de Développement du Riz) in 1970, is divided into 7 blocks each equiped by a pump except for the Block 1. The pump of the Block 3, however, stopped operation since 1991 after serious damage, and the pumps on the remaining 5 blocks are not always operating well due to frequent troubles.

Faced to those constraints, the farmers often suffer from the disturbance of irrigation programs which causes considerable delay of seeding date or retard in rice growth giving rise sometimes to complete death of the plants. Under those conditions, the farmers have been obliged to grow rice as it were "rain-fed", or completely abandon the growing rice. Consequently, in 1993, rice was harvested only in 226 Ha on the total area of 422 Ha. Moreover, the obtained yield was as low as 0.75 T/Ha in spite of the potentiality of more than 3 T/Ha when evaluated from the field survey (the Activity Report of Direction of the Department of M'Bahiakro, 1993; see also Fig. 4-3-4 in Chapter 3, section 3-3-2, and Annex D-4). Similar damages in rice production derived from the obsolescence of pumps and other installations have frequently repeated themselves in recent years, resulting in the decrease of farmers' income and the loss of farmers' capacity to apply sufficient amount of inputs, which accelerated in turn the further reduction in yield. Thus, placed in the difficult conditions mentioned above, the farmers expressed their strong desire to rehabilitate the perimeter.

(2) Dienzou Area

Field inquiries on the crop culture and farming practices were performed by the visit and hearing in the villages concerned with the project. Inspections of farms were also carried out if necessary. A typical example of Kouadianikro village is briefly described below.

42 farmers have grown upland rice on rain-fed farms betweem 0.5 and 1 Ha this year. However, no information was obtained about total acreage of rice culture and average size of rice farms. According to the responsibles of the village, rain-fed rice culture was introduced in relatively recent years, being mainly carried out by younger generations. To their opinion, the practice of growing rice is not easy for aged farmers due to lack of knowledge and physical power.

Growing practice of upland rice is as follows: After slash-and-burn of the fallow land, cleaning and soil preparation are done by daba (a sort of hand-hoe) and machette (a hatcher-like knife), then upland rice is seeded by broadcasting. No manure is applied at all. Weeds are controlled twice by machette during growing season. When the grains are ripe, the ears are cut in length of 30-40 cm from the top by the use of small knife (coupe-coupe), tied in bundles and dried on the farm for several days, then transported to the village where they are piled in "Tangana", a cylindrical heap artistically interstratified, for storage until sold or consumed domestically. Though no information about yield was obtained by the hearing of village people, field observation and rice sampling in one of the grower's farm suggested that it might be around 0.6 T/Ha (see Annex D-4). Upland rice is grown generally in association with maize, but the cropping density of the latter is quite low. After cropped rice for 1 or 2 years, the farmers let the field in fallow for 4-6 years.

Every farmer of the village cultivates yam, as it constitutes the basic food for Baoule, a major ethnic group in the area. Common practice of growing yam is as follows.

After slash-and-burn of the fallow land, soil is heaped up by daba in the mounds about 35 cm high and 80-100 cm in diameter, then cut pieces of yam tuber are planted on the top. Around those mounds, the associated crop as cassava, maize, banana plantain and some vegetables, tomoto, egg-plant, red pepper, okra etc., are commonly grown (see Annex D-1). In the first year, maize, vegetables and yam are harvested successively, and cassava and banana in the next year, then the growing of banana continues for further 2 years. At the end of this culture the cropped lands are put into fallow to recover soil fertility for 7 years or more. In this case also, crops are grown without any fertilizer, if weed control is done several times by daba or by machette.

Other than the vegetables associated with yam culture, a women group of the village are allocated small vegetable gardens where they grow tomato, red pepper, egg-plant, okra and peanut to be sold in the local markets.

Thus, the agricultural activity in this area is clearly characterized by the agriculture for subsistence. Cash income of the village people so far depended entirely on the coffee culture, but it declined year by year since the big drought of 1983/84 which destroyed seriously the plantations. On the other hand, the demand in money is increasing uninterruptedly for the necessity of various expenses, for example, education of children, medical care of the family, purchase of foodstuffs like salt, sugar, vegetable oils and others on local markets, and eventual expenses for marriage, funeral and so on. One of the purposes of upland rice culture is to find a compensatory resource for cash income lost by the decline of coffee production, but it is largely insufficient to cover the necessary money

due to unstable climate and unskilled technology of rice culture. In those circumstances, farmers in the area strongly desire the execution of the project.

(3) Yannon Area

The villages concerned with the irrigation development project were visited to inquire the situation of agriculture by hearing and field survey. Here, a typical example of Gbanan Koffikro village is described.

53 young farmers cultivate upland rice this year in this village. The old leaders told that the rice growers remain still minority in the village, though rice culture has a history as long as several ten years, being introduced by a few farmers in early 1950s. However, upland rice culture showed a rapid expansion in recent years in parallel to the decline of coffee and cacao production which is, in fact, completely abondoned in this village. The practices of upland rice culture is similar to those in Dienzou area, except for the hill seeding instead of broadcasting.

Here also, yam is grown by all farmers as basic food because the village people consist exclusively of the Baoule ethnic group. Cultural system of yam is practically the same as in Dienzou area, but the farmers here grow maize with or without peanut after the associated culture of yam and cassava, then let the land in fallow for 3 years before upland rice or 10 years before yam culture.

(4) Eholie Area

The villages concerned with the project were visited to study the situation of agriculture by hearing. An example of Assie Koumassi village is presented here.

Differing from the two areas mentioned above, all farmers of the village continue coffee and cacao culture, though the production is diminishing year by year. To the village chief's opinion, decrease in production of coffee and cacao is attributed essentially to the outbreak of pests, ageing of trees and disappearance of forests adapted to new plantation, and not to the direct effects of drought.

Nearly half of the village farmers grow upland rice since early 1980s for the purpose of selling and domestic consumption. According to the rough estimation by the village leaders, rice growers sell about half of the production and consume the other half domestically.

The majority of village people belongs to the Agni ethnic group. Although the Agni people here hitherto has consumed plantain banana and yam as basic food, they are obliged to eat more yam by the reason of insufficient production of plantain banana due to climate change as well as the gradual disappearance of productive forests. Consumption of rice has a character of supplementary food in the off-season of yam.

Practices of upland rice and yam culture are quite similar to the two areas described above.

(5) Atofou Area

The villages concerned with the irrigation development project were visited to inquire the situation of agriculture by hearing and field survey. Here, a typical example of N'Drikro village is described.

The village of N'Drikro shows an originality in ethnic composition. If the majority of the village people consists of the Agni ethnic group, some minor groups such as Dioula and Senoufo, who had migrated as hired labor from the northern part of Côte d'Ivoire, Burkina Faso or Mali, have settled there for about 40 years.

As regard to upland rice culture, only 15 young Agni farmers are engaged in this activity whereas most of the Dioula/Senoufo farmers, 30-35 in number, have been growing rain-fed rice since the beginning of their settlement. This is because Dioula and Senoufo are origianlly rice growers with abundant knowledge and experiences for it, while the Agni farmers started upland rice culture just several years ago after the decline of coffee and cacao production. The fact that the rice growers in Agni group belong to young generation seemed to reflect this history.

Both ethnic groups grow rice by similar practices to those mentioned before. Slight difference, however, is observed between them; Dioula/Senoufo group grows rice successively for 2 years or so on the same land, while Agni group abandons the rice cropping land after 1 year's culture because of, to their opinion, vigorous emergence and growth of weeds. The sampling survey of upland rice on one of the Dioula farmer's farms indicated the yield level of 2 T/Ha (see Annex D-4), suggesting their high technology of rain-fed rice culture. Moreover, the duration of fallow period is suppressed to 3 years today as a result of land shortage marked particularly in recent years.

The people's basic food has been yam and plantain banana for Agni, and rice and maize for Dioula and Senoufo. At present days, however, both groups consume more yam

as daily food due to the decrease in banana plantain production for Agni and the assimilation of eating habit of the majority for Dioula/Senoufo group. This fact explains why nearly all farmers of the village grow yam regardless of the ethnic group. The practices of growing yam are the same as described before.

5-5-2 Agricultural Production Program

(1) M'Bahiakro Area

If the perimeter of M'Bahiakro is rehabilitated accompanied with the construction of a low dam across the N'Zi, the perspective of double cropping of rice as well as dry season production of vegetables under irrigation will be opened. Therfore, the programs for land use and cropping pattern proposed in the Master Plan can be successfully adopted to this perimeter after rehabilitation. Therefore, the proposed program would consist of double cropping of rice and off-season culture of vegetables in dry season.

As for rice culture, the variety Bouake 189 is recommended. The growth period of this variety is 130 days (Poisson C. and Doumbia S: Variétés Nouvelles de Riz, Nouvelles Editions Africaines, 1987), and presents no constraints for double cropping. The introduction of new varieties such as BS 365 or Gulf Mount can be considered in some cases. Taking the double cropping of rice into account, it is requested to save water by utilizing rainfall as much as possible even in irrigated culture, to meet the harvesting time to sunny months, to insert sufficient intervals between two cropping seasons and to conduct cleaning of farm after harvest and soil preparation for the following crop. On the basis of these conditions, the most favorable cropping calendar will be as follows: seeding at the middle of March and harvest at the end of July by the first crop, and seeding at the middle of September and harvest at the end of January by the second. Type of rice culture is supposed to be based on direct seeding by broadcast before or after submersion of the field. In case of small-scale farming, however, the method of hill seeding would be successfully applied to save the amount of seeds and to facilitate manual weeding during the season. The proposed cropping calendar involves intervals of 30-40 days between two crops to carry out a series of works necessary for double cropping of rice; harvesting, collect of products, plowing, fertilizer application, submersion of the fields etc. It is, however, not always easy to complete those works within a month or so. Therefore, the introduction of certain agricultural machines together with the systematic management of works and irrigation by the GVC(s) (Group of cooperative vocation). The criteria of types and numbers of agricultural machines to be equipped in the perimerter are stated in 4-5-1 of the Chapter 4.

The rate of double cropping is fixed as 170 % at the initial stage, taking into consideration the availability of family labor and efficiency of mechanical operations.

With respect to vegetable culture, tomato and onion are proposed to be main crops, because those two vegetables would be easily accessible to the markets, and would give relatively higher profits. The proposed rotation is 4 years system consisting of Tomato - Onion - Okra - Unmature maize, as to prevent unfavorable effects of continous cropping of the same species (refer to the document; Projet d'aménagement d'un bas-fond pour la riziculture irriguée à Adahou (S/P Dimbokro), CIDV, 1988). More profitable off-season production of tomato and onion can be practiced in the perimeter so that the growing seasons of these vegetables are fixed as follows: tomato is transplanted in October and harvested from December to February, and onion is transplanted in November and harvested in March. If the proposed rotation consists of single crop culture per year, the possibility of double cropping is not excluded because it will be possible to insert some vegetables of short growth period before tomato or onion if family labor permits it.

In the plan, it is supposed that every farmer grows vegetables in their small gardens situated independently of rice fields as in the manner of traditional vegetable culture in Côte d'Ivoire. In those conditions, watering of vegetables would be carried out by the use of watering cans, taking water from small ponds or farm canals equipped in the perimeter. However, furrow or border irrigation using plastic tubes and siphons can be considered if big farmers proceed a monoculture of vegetables.

Allotment ratio of irrigated land will be 80 % to rice and 20 % to vegetables. Vegetable production on 20 % of land would be the profitabe limit from the viewpoint of present situation of local markets and available family labor.

On the basis of discussions made with the ANADER experts, target yields are fixed as follows: 6 T/Ha for rice in both seasons, 30 T/Ha for tomato, 30 T/Ha for onion, 5 T/Ha for okra and 75,000 cobs/Ha for unmature maize. Yield target of 6 T/Ha for rice, though rather higher than that of the Master Plan of Agricultural Development 1992/2015, is to be attained within 5 years subsequent to the completion of construction works, if technical support by the ANADER is as sufficient as the perimeter of Sakassou. The reasons for it is that the latter perimeter has already realized 5 T/Ha of yield in the third year after starting of rice culture, and that installation levels in the present project will be superior to those of Sakassou. Technical guideline of irrigated rice culture is attached to the Annex (see Annex D-2).

The proposed cropping pattern in conditions mentioned above is the same as that

illustrated in Fig. 4-5-1 in the paragtaph 4-5-1 of the Chapter 4.

(2) Dienzou, Yanmon, Eholié and Atofou Areas

Since the irrigation water will be available all year round after the construction of the dams, and the farmers in the area have experience in upland rice and vegetables culture, the production program based on double cropping of rice and off-season culture of vegetables can be recommended. The land use and cropping pattern to be applied do not differ from those described in the perimeter of M'Bahiakro, except for the irrigation by gravity. Thus, the cropping pattern under gravity irrigation is the same as that illustrated in Fig. 4-5-1 in the paragraph 4-5-1 of the Chapter 4.

Target yields together with the cropping rate of rice and vegetables are fixed at the same level as the perimeter of M'Bahiakro.

Oher than the irrigated perimeter for rice and vegetable production, 10-25 Ha of the land situated in down-stream or peripheries can receive supplementary irrigation by utilizing drainage water from the perimeter or occasional surplus of the reservoir at the time of seeding or drought. The farmers can choose freely the land use and cropping system in those lands depending on their demand. However, the following systems would be generally recommendable. 4 years rotation of food crop production: Associated culture of yam and cassava - Peanut - Maize on the slope, and 3 or 4 years rotation of cash crops: (Upland rice) - Cotton - Peanut - Maize or 7 years system of Banana Plantain for 4 years - Forage crops for 3 years on the low land. The establishment of nurseries of coffee or cacao might be taken into account from the standpoint of rural development because the favorable conditions of supplementary irrigation will be born.

5-5-3 Animal and Fish Production Program

Along the government policy presented in the Master Plan of Agricultural Development 1992/2015, a development program of animal husbandry should be considered in the villages concerned with project, though farmer's experiences in raising animals, cattle in particular, are not sufficient yet. The substantial base for it is that the by-products of perimeters, the brans and straw of rice, vegetable residues and others, would be successfully utilized as fodder for animals in dry season, and further, the construction of reservoirs would facilitate the setting of water drinking points in the vicinity of the perimeter.

The number of animal heads that can be introduced by the completion of perimeters is

estimated as follows. Assuming that the animals raised by grazing take digestible nutrients (expressed in TDN or Forage Unit) and digestible crude protein (expressed in DCP) in the proportion of 50 % in natural pasture, 5 % in artificial grassland, 20 % in rice straw and 25 % in rice bran, and that 50-60 % of rice bran are destinated to animal breeding, the capacity of the irrigated perimeter to support animal husbandry would be 1 cattle and 1.5 sheep per Ha (see Annex D-5). Consequently, the animal heads per perimeter are defined with the herd size of 20-30 cattle and 30-50 sheep per village as shown in Table 5-5-1.

Table 5-5-1 Development plan of animal husbandry in priority area

Name	Irrigable area (ha)	Possible heads per perimeter		Number of concerned villages	Planned herd size per village	
		Cattle	Sheep		Cattle	Sheep
M'Bahiakro	450	450	675	8	30	50
Dienzou	90	90	135	3	30	50
Yanmon	65	65	98	3	20	30
Eholie	105	105	158	3	30	50
Atofou	190	190	285	3	60	100

In the perimeter of M'Bahiakro, where the capacity is important, it would be rather realistic to start with a relatively smaller herd size taking into account the long distance between the perimeter and villages and the potential conflicts that may arise between animal breeders and cultivating farmers when animals are grazed in the vicinity of the perimeter. On the other hand, the herd size to be recommended is doubled for Atofou area by the consideration that the farmers of Fronobo, one of the villages concerned, has already started the cattle breeding several years ago.

The construction of small size ponds for fish culture is also recommended in the perimeters from the viewpoint of improving nutritional state and income of the village people as the Master Plan of the Government stresses it. By the introduction of fish culture, about 500 Tilapias of fish harvest will be expected from a pond of 300 m² every 6 months. In this case, harvest residues derived from the perimeter or farms in the vicinity will be utilized as nourishments for fish.

5-5-4 Farming Plan

Agro-economic survey carried out in this study revealed the mean house-hold size and mean annual revenue and expense in the development priority area as shown in Table 5-5-2 (see also Annex D-6).

Table 5-5-2 Average composition of households in the development priority area

	M'Bahiakro	Dimbokro	Bocanda	Bongouanou	M'Batto
Household compostion:					
Number of total member	8.4	8.4	10.9	8.7	5.8
Mean number of adult men	1.4	2.3	2.0	2.3	1.5
Mean number of adult woman	2.3	2.3	2.9	2.1	2.0
Mean number of children	4.7	3.8	6.0	4.3	2.3
Number of active members	3.1	4.9	3.3	4.4	3.0
Mean income and expenses (CFA F/year)					
Income	55,356	228,887	94,909	269,719	137,638
Expenses	87,178	280,892	235,767	327,203	477,775

Source: Projet de Développement Rural Intégré de la Moyenne Vallée du N'Zi: Volet Agro-économique (Djoussou Haly Louise et Angoran Ayemou Odile), SIRES, 1994.
As concerned with M'Bahiakro area, cited from the report of the same title of 1993.

On the basis of this table, the household consisting of 5-6 family members with 3 actives, and of 8-10 family members with 3-4 actives can be drawn as model farming units. On the other hand, the household of younger generation consisting of 4-5 family members with 2 actives should also be added as another model for the purpose of the project.

Thus, based on these 3 models of household, the corresponding farming sizes are defined as shown in Table 5-5-3.

Table 5-5-3 Farming unit models

	Number of total members	Number of active members	Area of irrigated farm (ha)		Area of rain-fed farm (ha)
			Rice	Vegetables	
Model I	4-5	2	0.4	0.1	0.5
Model II	5-6	3	0.8	0.2	1.0
Model III	8-10	3-4	0.8	0.2	1.0

Necessary areas of rain-fed farms are fixed on the assumption that every member of farmers' family consumes yam as basic food in the proportion of 1 T per capita and per year.

The model farming units require monthly the family labor shown in Table 5-5-4 to cover the necessary works (see Annex D-7). It should be noticed that the calculation by vegetable production was based on tomato and onion culture, the most labor-taking ones, to simplify the cases, though the proposed rotation includes okra and ummature maize other than tomato and onion.

Table 5-5-4 Monthly family labor necessary for the model farming units

(man-day)

(1) Model I (irrigated farm 0.5 ha, rain-fed farm 0.5 ha)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rice	6.2	2.7	3.2	4.8	5.6	9.2	8.8	2.6	2.2	3.4	3.9	6.4
Tomato	2.1	1.2	0.5	-	-	-	-	-	1.1	2.5	1.7	2.0
Onion	1.8	1.9	0.9	1.0	-	-	-	-	1.0	0.5	2.0	1.4
Yam	4.5	11.0	12.5	5.0	8.0	1.0	-	1.0	4.0	1.0	1.0	7.5
Total	14.6	16.8	17.1	10.8	13.6	10.1	8.8	3.6	8.3	7.4	8.6	17.3

(2) Model II (irrigated farm 1.0 ha, rain-fed farm 0.5 ha)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rice	12.3	5.4	6.4	9.6	11.2	18.4	17.6	5.4	4.5	6.7	7.8	12.9
Tomato	4.2	2.3	1.0	-	-	-	-	-	2.2	4.9	3.4	4.0
Onion	3.6	3.7	1.7	2.0	-	-	-	-	2.0	1.0	1.0	2.8
Yam	4.5	11.0	12.5	5.0	8.0	1.0	-	1.0	4.0	1.0	1.0	7.5
Total	24.6	22.4	21.6	16.6	19.2	19.4	17.6	6.4	12.7	13.6	16.1	27.2

(1) Model III (irrigated farm 1.0 ha, rain-fed farm 1.0 ha)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rice	12.3	5.4	6.4	9.6	11.2	18.4	17.6	5.4	4.5	6.7	7.8	12.9
Tomato	4.2	2.3	1.0	-	-	-	-	-	2.2	4.9	3.4	4.0
onion	3.6	3.7	1.7	2.0	-	-	-	-	2.0	1.0	1.0	2.8
Yam	9.0	22.0	25.0	10.0	16.0	2.0	-	2.0	8.0	2.0	2.0	15.0
Total	29.1	33.4	34.1	21.6	27.2	20.4	17.6	7.4	16.7	14.6	17.1	34.7

Labor peak appears in dry season from December to March in all models, and it is due properly to the yam culture rather than rice and vegetables. In fact, growing of yam requires much labor for the preparation of moulds, planting seed tubers, harvest and storing. Moreover, the farming works can be sufficiently covered by family labor in any model, even if an assumption is taken that half of active members consists of women and that their actual capacity to be devoted to farm activities would be estimated as about half of the normal due to heavy housekeeping works.

5-5-5 Farming Profitability

(1) Irrigated Perimeter

The gross benefit per Ha of irrigated land as calculated on the basis of cropping pattern and cultural guidelines proposed in the section 5-5-2 is shown in Table 5-5-5 (see Annex D-2, D-3 and D-8).

Table 5-5-5 Mean gross benefit per ha of irrigated field per year

(A) Gravity irrigation (CFA F/ha/year)

Crop		Cropping percentage	Sale proceeds	Production costs	Gross benefit
Rice culture	Rice, 1°crop	80%	528,000	200,312	327,688
	Rice, 2°crop	56%	369,000	140,218	229,382
Vegetable culture	Tomato	5%	135,000	29,554	105,446
	Onion	5%	135,000	29,051	105,949
	Okra	5%	15,500	9,023	5,977
	Unmature maize	5%	60,000	18,753	41,247
Total		156%	1,242,600	426,911	815,689

(B) Pumping irrigation (CFA F/ha/year)

Crop		Cropping percentage	Sale proceeds	Production costs	Gross benefit
Rice culture	Rice, 1°crop	80%	528,000	206,712	321,288
	Rice, 2°crop	56%	369,000	144,698	224,902
Vegetable culture	Tomato	5%	135,000	31,154	103,846
	Onion	5%	135,000	30,651	104,349
	Okra	5%	15,500	10,623	4,377
	Unmature maize	5%	60,000	20,353	39,647
Total		156%	1,242,600	444,191	798,409

In the case where the union of GVC or the cooperative undertakes milling of rice by the request of farmers who want to sell their products not as grains but as white rice, the gross benefit increase markedly because the actual price system is much in favor of white rice. Thus, taking the milling rate as 65 %, the milling charge to be paid by farmers to the union as 25 FCFA/Kg of white rice, and the market price of white rice as 300 FCFA/Hg, the producer's gross benefit will increase considerably as shown in Table 5-5-6 (see Annex D-8).

Table 5-5-6 Mean gross benefit per ha of irrigated field per year in the case where rice is sold after milling

(CFA F/ha/year)

	Crop	Sale proceeds	Production costs	Gross benefit
Gravity irrigation	Rice, 1° crop	936,000	278,312	657,688
	Rice, 2° crop	655,200	194,818	460,382
	Vegetables	345,000	86,381	258,619
	Total	1,936,200	559,511	1,376,689
Pumping irrigation	Rice, 1° crop	936,000	284,712	651,288
	Rice, 2° crop	655,200	199,298	455,902
	Vegetables	345,000	92,781	252,219
	Total	1,936,200	576,791	1,359,409

(2) Rain-fed Land

The production program adopted on rain-fed land in the development priority area is assumed to consist of two types; one is production system of yam on inclined land, and the other, production system of banana plantain or cash crops on lowland, both managed in intensified practices by the effective use of supplementary irrigation. The expected gross benefit of those systems is given in Table 5-5-7 (see Annex D-2 and D-8).

Table 5-5-7 Mean gross benefit per ha of rainfed field per year

(A) Food crop production

Cultural system	Crop	Yield (t/ha)	Sale proceeds	Production costs	Gross benefit
	Yam	15.0/2 *	450,000	108,250	341,750
Yam** -	Cassava(2 years)	15.0/2 *	300,000	105,500	194,500
Cassava -	Peanut	3.0	180,000	89,000	91,000
Peanut -	Maize	3.0	150,000	113,450	36,550
Maize	Total	-	1,080,000	416,200	663,800
	Annual mean	-	270,000	104,050	165,950

* Yam is grown in association with cassava in equal proportion.

(B) Annual cash crop production

Cultural system	Crop	Yield (t/ha)	Sale proceeds	Production costs	Gross benefit
	Rainfed rice	2.5	275,000	150,670	124,330
Rainfed rice-	Cotton	1.5	225,000	118,825	106,175
Cotton-	Peanut	3.0	180,000	89,000	91,000
Peanut	Maize	3.0	150,000	113,450	36,550
-Maize	Total	-	830,000	471,945	358,055
(4 years)					
	Annual mean	-	207,500	117,986	89,514

(C) Banana plantain production

Cultural system	Crop	Yield (t/ha)	Sale proceeds	Production costs	Gross benefit
Banana plantain (4 years)- Forage crops (3 years)	Banana plantain	8.0	1,600,000 x 2 fois	122,000 x 2 fois	1,478,000 x 2 fois
	Annual mean	-	457,143	34,857	422,286

(3) Cash Income of Model Farming

Cash incomes of the model farming I, II and III are examined here on the basis of profitability of cropping systems mentioned above. The hypothesis on the rate of sale and

domestic consumption of the products is as follows; the products on rain-fed land as yam, cassava and others are destinated wholely to domestic consumption, and as for rice, after subtracting 250 Kg/Ha for seeds of the next year and 100 Kg per capita for domestic consumption for every member of the family, the rest is entirely destinated for sale. Vegetables are produced exclusively for market. In those conditions, the calculation of cash income after subtraction of total costs for production gives the results shown in Table 5-5-8.

Table 5-5-8 Cash income of model farming units in the irrigated perimeter

Model farming unit		Income from rice			Income from vegetables	Total cash income
		Amount of sold rice	Production costs	Net income from rice		
G	Sold in grain rice					
r	Model I	3,410 Kg	170,265	204,835	129,310	334,145
a	Model II	7,220	305,530	453,670	129,310	334,145
v	Model III	6,820	340,530	409,670	258,619	668,289
i	Sold in white rice					
t	Model I	2,216 Kg	236,565	428,235	129,310	557,545
y	Model II	4,693	673,130	934,770	258,619	1,193,389
	Model III	4,433	473,130	856,770	258,619	1,115,389
P	Sold in grain rice					
u	Model I	3,410 Kg	175,705	199,395	126,110	325,505
m	Model II	7,220	351,410	442,790	252,219	695,009
p	Model III	6,820	351,410	398,790	252,219	651,009
i	Sold in white rice					
n	Model I	2,216 Kg	242,005	422,795	126,110	548,905
g	Model II	4,693	484,010	923,890	252,219	1,176,109
	Model III	4,433	484,010	845,890	252,219	1,098,109

Comparing the obtained results with the household economy of agro-economic survey given in Table 5-5-2, the cash income of model farmings will increase markedly and cover sufficiently the necessary annual expenses even if rice is sold before milling. In the case where rice is sent to market in the form of white rice milled by the union of GVC, cash income will show further increase by 60 % or more, resulting in visible improvement of living standard of the farmers' family.

With respect to animal husbandry and fish culture, the evaluation of profitability is quite difficult at present state. At any rate, to gain a satifactory benefit would be difficult at

least at the initial stage of introduction. Accordingly, the development of animal production should be considered in long-term perspectives.

5-6 Agricultural Supporting Plan

5-6-1 Objectives

The agricultural extension activities in the M'Bahiakro development area are presently handled by one extension worker of former CIDV and, therefore, suffer from insufficient number of personnel in supplying such technological assistance as production skill instructions, irrigation and water management planning and organization structuring. In addition, the farmers in the four new development area, in effect, have few opportunities to receive agricultural extension services. Furthermore, the farmers in each area have barely access to agricultural credits, resulting in such serious problems as reduced cultivation area because of the operation fund shortage, as seen in M'Bahiakro development area.

The agricultural supporting plan has the purpose of establishing supporting provisions which are necessary to achieve the planned farm operations in the study areas.

5-6-2 Description of the Plan

(1) Extension Services

Upon the introduction of modern agricultural techniques to the study areas of this plan, comprehensive and mobile extension services will be necessary for the areas of Dienzou, Yanmon, Eholie and Atofou, where irrigation is introduced for the first time. As mentioned in 4-4-6, a supporting unit of extension services which consists of five specialists (respectively in cultivation, irrigation, organization, marketing and rural animation), will be established to give assistance to the farmers in each area. This supporting unit, in consultation with the farmers in each area, will prepare an overall support plan, on which each extension worker will base his or her activities in closely assisting farmers through a Training and Visit (T&V) System.

It is preferred that one fish breeding specialist, if necessary, join the unit in addition to the above mentioned members.

It is recommended that one supporting unit per prefecture be established corresponding to the ANADER prefectural office, which plays a central part in extension operations. Thus there will be a total of three supporting units; one for M'Bahiakro

development area, one for Dimbokro prefecture including Dienzou and Yanmon areas and one for Bongouanou prefecture including Eholie and Atofou areas.

Table 5-6-1 Establishment of supporting Unit

District	No. of Development Unit	Areas
M'Bahiakro	1	M'Bahiakro area
Dimbokro	1	Yanmon, Dienzou area
Bongouanou	1	Eholie, Atofou area
Total	3	5 areas

(2) Farm Input Supply system

Because the farm input supply system is an essential factor for the success of the farm operations, it is suggested that the GVC management committee of farm input, under the guidance of the Project Office, sell on credit and supply such farm input as fertilizers, agricultural chemicals and fuel to the farmers. Accordingly, the GVC should store and distribute the farm input during the farming season, and collect the debts after harvesting. As mentioned in 4-6, the fund will be provided from the Project Fund.

(a) Managing Organization

The GVC itself will buy the necessary farm input, using the fund rented from the Project Fund. The GVC, under its own responsibility, will distribute the farm input to the farmers and collect the debts after harvesting.

(b) Required Credit

The estimated amount of credit required to cultivate paddy rice and vegetables in each development priority areas, based on the prices of October 1994, is shown in the following table.

Table 5-6-2 Credit Requirement of Farm Input (annual) in the Development Areas

Development areas	Paddy (ha)	Vegetables (ha)	Credit requirement (1000 FCFA)
1. M'Bahiakro	530	78	130,952
2. Dienzou	105	16	22,999
3. Yanmon	77	11	16,731
4. Eholie	124	18	26,776
5. Atofou	224	33	48,856
Total	1,061	156	264,314

(3) Lease Services of Agricultural Machinery

According to the agricultural production plan, hand tractors, threshers and rice mills are the agricultural machines that are going to be introduced. The GVC union will provide lease services of these machines to the farmers through each GVC. The fund required to purchase these machineries will be provided from the Project Fund.

(a) Managing Organization

The GVC union itself will purchase the necessary agricultural machinery with the fund loaned by the Project Fund. The GVC union will collect the lease charges in order to repay the loan and accumulate the fund for machine replacements.

It is recommended that the lease charges of agricultural machinery follow the charges shown in Table E-2-15, with the charges for hand tractor and thresher being approximately 30,000 and 10,000 CFA F respectively.

(b) Required Credit

The estimated amount of credit required to buy the necessary agricultural machinery, based on the prices of October 1994, is shown in the following table.

Table 5-6-3 Credit requirement of agricultural machinery

GVC union	Hand Tractor		Thresher		Rice mill		Trucks		Total
	No.	1,000 FCFA	No.	1,000 FCFA	No.	1,000 FCFA	No.	1,000 FCFA	1,000 FCFA
M'Bahiakro GVC center	31	58,900	16	19,200	1	22,320	1	26,700	127,120
Dimbokro Cooperative entente	11	20,900	5	6,000	1	13,080	1	26,700	66,680
M'Batto GVC	20	38,000	11	13,200	1	13,080	1	26,700	90,980
Total	62	117,000	32	38,400	3	48,480	3	80,100	284,780

(4) Training

The farmers need various instructions and training to accomplish the new style of agricultural operations. In this program, the daily technical training will be provided by the enhancement support units, while the training for operation and repair of the agricultural machines will be provided at the Grand-Lahou Agricultural Machinery Training Center of ANADER.

(a) Training by the Enhancement Support Units

The enhancement support units emphasizes on the training of the GVC in organizational management and in management and maintenance of the irrigation facilities. On-the-job training in operational management, including clerical works, will be provided to the GVC staff by the organization specialists and others from ANADER.

The management and maintenance of the irrigation facilities will be based on the manual for facilities management, while the person in charge of the training in the support unit will provide on-the-job training to the farmers so as to enable them to operate and manage the irrigation facilities themselves.

(b) Training at the Grand-Lahou Agricultural Machinery Training Center

The training required for the operation and repair of grain threshing machines and rice polishing machines, which are to be implemented, are provided at the Grand-Lahou Agricultural Machinery Training Center. Since tillers and grain threshing machines will be owned by the GVC union and leased to each GVC, at least one trainee from each GVC and one from the union will be trained for each machine. As for the rice polishing machines, the delegation of two or more trainees from the union will be required because the GVC union will own these machines and carry on the rice polishing operations. Assuming that the agricultural machinery training is provided in addition to the courses at the Training Center, at least the following number of staff and budget will be required (see Table 5-6-4).

Table 5-6-4 Agricultural machinery training plan

Area	Course	Persons	Budget CFA F
M'Bahiakro	Operation and Maintenance	17	1,890,000
Dimbokro	Operation and Maintenance	7	840,000
Bongouanou	Operation and Maintenance	7	840,000
Total		31	3,570,000

Note: Refer to table E-2-10 to 12

5-7 Farmer Organization Promotion Program

5-7-1 Purpose

(1) M'Bahiakro Development Area

M'Bahiakro development area consists of seven blocks and a total of 304 farming members, including one GVC and four Informal Groups (GI).

Though officially organized, these farmer groups in reality have such problems as agricultural operation fund shortage and water shortage, and most of the activities heavily rely on the individuals, not taking full advantage of the group structure.

(2) New Development Areas (Dienzou, Yanmon, Eholie and Atofou)

In these areas, the farmer groups are structured around the GVC's that are mainly engaged in the coffee and cacao production. However the farmer organizations are losing their importance due to the decrease in production and reduced number of cultivators of these crops. Meanwhile, a move toward the restructuring of the GVC's is observed in Kouakro Village in Atofou Area, in addition to the re-establishment of the GVC union in M'Batto county. This restructuring of the GVC's occurred in response to the diversification of crops. The restructuring extended the previous GVC activity scope, which used to be limited to the production of coffee and cacao, to include the rice and vegetable cultivation as well.

This farmer organization promotion program establishes the farmer organizations and activity plans necessary to carry on the planned agricultural operations in the above mentioned areas.

5-7-2 Description of the Program

(1) M'Bahiakro Development Area

(a) Establishment of the GVC Center

In M'Bahiakro development area, the GVC center will be established with a council of leaders of seven newly restructured GVC's (see Figure 5-7-1). The GVC center will coordinate GVCs and manage the following points.

- Distribution and management of the equipment for agricultural production

- Distribution and management of the agricultural machinery and its parts
- Joint shipment of the agricultural production
- Maintenance and management of the dam and related facilities as well as the primary drainage ways
- Development of rice polishing operations

(b) Restructuring of GVC's

It is recommended that the existing four GI's and one GVC (which consists of three farmer groups) be restructured and transformed into seven GVC's corresponding to the seven farmer groups. Each GVC must be an independent organization equipped with the four functions as described in 4-4-7.

(2) New Development Areas (Dienzou, Yamnon, Eholie and Atofou)

(a) Restructuring of the Prefectural Federation of the Agricultural Cooperative Associations and the Establishment of the GVC Union

i) Restructuring of the Prefectural Federation of the Agricultural Cooperative Associations in Dimbokro Prefecture

The prefectural federation of the agricultural cooperative associations in Dimbokro prefecture will be restructured through the reinforced market product distribution activities. The reinforcement will emphasize the following points.

- Expansion of rice polishing operations
- Increase in market distribution abilities
- Empowerment of distribution specialists

ii) Re-establishment of the GVC Union in M'Batto County

There used to be a GVC union in M'Batto county, but it has stopped its operation since 1992. In spite of such circumstances, however, a move by the farmers and the administration in this area to re-establish the GVC union has been taken place as of September 1994. Therefore, this program will support the re-establishment of the GVC union through the promotion of market distribution activities.

(b) Restructuring of GVC's

In each new development area, a new GVC (a member of the union), which consist of farmers of three to four associated villages, will be established under the support of the ANADER staff. This new GVC will have a larger scope of activities than before, expanding its activities to rice and vegetable cultivation. As described in 4-4-7, each GVC will be represented by a leader and has the following four committees:

- Committee for farm input management
- Committee for management of operation and maintenance of facilities
- Committee for management of machinery
- Committee for marketing management

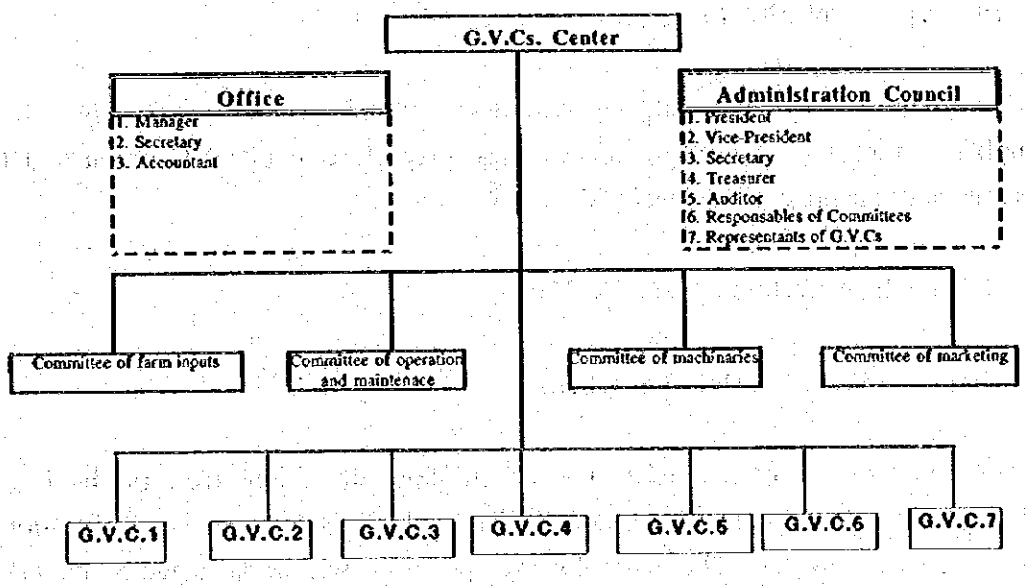


Figure 5-7-1 Proposed Organization of G.V.Cs Center in the M'Bahiakro development Area

5-8 Distribution and Agricultural Product Processing Plan

5-8-1 Purpose

In the part of the country, where the plan is to be implemented, the cultivation of coffee and cacao is not as common as before. Therefore, from the perspective of distribution, the sales of peanut, rice and vegetables has become an important source for cash income. Especially, cultivated rice and vegetables are becoming more than ever important cash crops.

The problems in the distribution of rice and vegetables, as pointed out by the farmers,

are mainly the shortage of transportation and the unstable crop prices. In order to cope with these problems, it may be worthwhile to carry on such operations as the joint shipment of the products, the collection of the distribution information and the reduction of the shipment cost by the cooperation of the groups.

The present marketing of the products is not working under its full advantage, because only a small sales quantity is handled at one time. However, this agricultural development program will provide the market with a substantial quantity of products, enabling an advantageous marketing through the joint shipment and sales. This program of the distribution and the processing of agricultural products has the purpose of reinforcing the distribution section of the farmer organization in order to promote the joint shipment and sales.

5-8-2 Description of the Program

The invigoration of the distribution and agricultural product processing will be accomplished through (a) reinforcement of the prefecture-level GVC union and (b) reinforcement of the project-site-level GVC's.

(1) Reinforcing the Prefecture-Level GVC Union

(a) Development of Rice Polishing Operations

The establishment of a consistent and continuous operations from production to processing by farmers will enable the value-added marketing and create an opportunity to return the profit to farmers. The rice polishing operations will be managed by the GVC union in order to secure a substantial quantity of polished rice. Three prefecture-level GVC's will be responsible for the rice polishing operations in their own prefecture's development priority areas under their hierarchical organization.

Table 5-8-1 Target area of rice milling

GVC Union	Target Area
M'Bahiakro GVC center	M'Bahiakro
Dimbokro cooperative entente	Yamnon, Dienzou
M'Batto GVC union	Eholie, Atofou

Note) Refer to Table E-4-1

i) Planned Amount of Rice Polishing

The output of polished rice is estimated based on the assumption that 20% of the unhusked rice produced in each development priority area is used for seed and self-consumption, and 80% will go through rice polishing with the polishing rate of 65%. According to the agricultural production plan, the output of unhusked rice of the development areas as a whole is estimated to be 5,300 tons / year. If 80% of this amount is polished, the output of polished rice will come to 2,756 tons / year . The planned amount of rice polishing is 2,120 tons for M'Bahiakro GVC center, 728 tons for the Dimbokro prefectural federation of the agricultural cooperative associations, and 1,392 tons for M'Batto GVC union.

Table 5-8-2 Planned amount of rice milling

GVC Union	Paddy			White rice production (t)		
	Rain season	Dry season	Sub-total	Rain season	Dry season	Sub-total
M'Bahiakro GVC center	1,248	872	2,120	811	567	1,378
Dimbokro cooperative entente	428	300	728	278	195	905
M'Batto GVC union	820	572	1,392	533	372	905
Total	2,496	1,744	4,240	1,622	1,134	2,756

ii) Performance of Rice Polishing Machines

Comparison of the processing performances of the 0.5 t/h- and 1.0 t/h-rice polishing machines shows that the 0.5 t/h-machine will suffice for the Dimbokro and M'Batto areas throughout the year. However, although the 0.5 t/h-machine can be useful in M'Bahiakro area, in the case of 16 hour operations, the 1.0 t/h-machine will be preferable in order to shorten the polishing period and enable advantageous marketing.

Table 5-8-3 Required period of rice milling

GVC Union	Capacity 0.5t/h		Capacity 1.0t/h	
	8h/day	16h/day	8h/day	16h/day
M'Bahiakro GVC center	530 days	265 days	265 days	132 days
Dimbokro cooperative entente	182 days	91 days	91 days	46 days
M'Batto GVC union	348 days	174 days	174 days	87 days

Therefore, the rice polishing machines to be implemented in each area will be as shown in the following table. The table assumes the daily operation time to be 16 hours.

Table 5-8-4 Implementation of rice mill

GVC Union	No.	Unit capacity	Daily capacity
M'Bahiakro GVC center	1	1.0t/h	16t/day
Dimbokro cooperative entente	1	0.5t/h	8t/day
M'Batto GVC union	1	0.5t/h	8t/day
Total	3	2.0t/h	32t/days

iii) Managing Organization

The rice polishing operations will be managed by the committee for marketing management of the GVC union. Although the priority is given to the members, the union will provide the service to both the member GVC's and non-member GVC's.

iv) Management

The union will collect the lease charge from those who use rice polishing machine to repay the loan and meet the maintenance and depreciation expenses. Taking the differences of the planned amount of rice polishing in various areas into a consideration, the polishing cost will be in the range of 8 to 12 CFA/kg. The cost, including the loan repayment, will be 11 to 16 CFA/kg.

Table 5-8-5 Milling cost and repayment

GVC Union	Milling cost (CFA F/kg)	Repayment (CFA F/kg)	Total (CFA F/kg)
M'Bahiakro GVC center	6.14	2.33	8.47
Dimbokro cooperative entente	8.71	3.80	12.51
M'Batto GVC union	6.72	2.24	8.96

Note: The milling cost includes the O&M cost, depreciation and interest (refer to table E-4-3 to 6). Repayment per Kg is based on the loan repayment of principal which is divided by the paddy amount for milling.

The average amount of rice milling charge by the private businesses is approximately 25 F/kg (in polished amount), and therefore the charge can be set at 15 to 25 F/kg for the members, taking the internal reserves into consideration.

The average amount of rice polishing charge by the private businesses is approximately 25 CFA F/kg (in polished amount), and therefore the charge can be set at 15 to 25 CFA F/kg for the members, taking the internal reserves into consideration.

(b) Warehouses

The warehouses will be constructed to store the unhusked rice collected from GVC's and to polish the rice. In M'Bahiakro development area, a warehouse with the capacity of approximately 2,000t will be constructed near M'Bahiakro to store unhusked rice. Existing warehouses will be used at the Dimbokro prefectural federation of the agricultural cooperative associations and at M'Batto county GVC union.

These facilities will have a storage capacity of approximately 2,000t of planned amount of unhusked rice. Details are provided below.

- Storage Capacity: As 1.0t of unhusked rice takes up the space of 1.6m3, total volume = 1.6m3 x 2,000t = 3,200m3. Assuming that the stack up is 5.0m high and the space loss is 10%, the area is approximately 700m2.
- Polished Rice: An area of 80m2 needs to be secured for good work efficiency.
- Office: 20m2 needs to be secured as the office. The required area, therefore, is 800m2.

(c) Securing the Transportation Means

The distribution of 6 ton-level trucks to the three GVC unions is planned in order to provide the GVC unions with crop collecting and transporting abilities. The distribution of trucks contributes to efficiently transport products from the farms in the development areas and/or from the warehouses of GVC's to the union, to reduce the cost and to enable the integration of the rice production and the rice polishing operations.

i) Managing Organization

The trucks will be managed by each GVC union. The committee of marketing management of the union will be in charge of the transportation plans and truck allocations. This committee, through arrangement with each GVC, will transport the cargo and collect the charges.

ii) Maintenance

The union will collect the transportation charges of the trucks, which include the

amount for repaying the loan and supporting the maintenance and depreciation expenses. The comparison of the transportation charges in each area is reviewed and shown in Table 5-8-6. Because the amount of charges depend on the amount of cargo and the transportation distances, the charges vary from 3.02 to 8.95 CFA/kg even if 100% of the products and materials for agricultural production is handled. These charges do not include the profit for the GVC union. The review of the charges is based on the following conditions:

- The trucks are bought with the loan. The loan period is 7 years.
- The products to be transported are limited to those produced in the development areas
- The transportation distance is from each GVC to the union.
- The transportation charges include the loan repayment and the maintenance and depreciation expenses. Thus, the transportation charges will become lower after 7 years when there is no longer such repayment.

(2) Reinforcement of GVC's

(a) Drying of Unhusked Rice

Because of the crop planting plan and planting period, only a little damage by the rain is expected on the paddy rice after harvesting. Therefore, the unhusked rice will be dried in the traditional way of sun drying, making use of the natural energy. The total of 62 concrete-made drying fields for the unhusked rice will be constructed in the farms, one (60m2) for each 10 ha for efficient grain threshing and drying of the unhusked rice after harvesting.

Table 5-8-6 Comparison of transportation charge

Cases(proportion of transportation amount)		100%	80%	60%	50%
1.M'Bahiakro area					
Price of truck	(1,000CFA)	26,700			
1-1 Transportation amount	(t)	4,539	3,631	2,723	2,270
1-2 Transportation cost	(CFA/kg)	2.04	2.45	3.15	3.70
1-3 Repayment	(CFA/kg)	0.67	0.84	1.12	1.34
1-4Transportation charge	(CFA/kg)	2.71	3.29	4.27	5.04
2.Dimbokro area					
Price of truck	(1,000CFA)	26,700			
1-1 Transportation amount	(t)	1,564	1,251	938	782
1-2 Transportation cost	(CFA/kg)	6.11	7.32	9.33	10.94
1-3 Repayment	(CFA/kg)	1.94	2.43	3.24	3.88
1-4Transportation charge	(CFA/kg)	8.05	9.75	12.57	14.82
3.M'Batto area					
Price of truck	(1,000CFA)	26,700			
1-1 Transportation amount	(t)	2,980	2,384	1,788	1,490
1-2 Transportation cost	(CFA/kg)	4.26	4.89	5.95	6.79
1-3 Repayment	(CFA/kg)	1.02	1.27	1.70	2.04
1-4Transportation charge	(CFA/kg)	5.28	6.16	7.65	8.83

Note;

(1)Transportation amount are involved the paddy and vegetables production, farm input.

(2)Price of truck is as of October 1994 without taxes.

(3)Repayment is assumed on 7years term with the interest of 7.5% per year. The figure indicates the repayment per kg of the principal.

(4)Refer to Table E-4-6 for the details.

Table 5-8-7 Paddy drying floor in the development areas (plan)

Development Areas	Paddy area (ha)	Drying floor (No.)
1. M'Bahiakro	312	31
2. Yanmon	45	5
3. Dienzou	62	6
4. Eholie	73	7
5. Atofou	132	13
Total	624	62

(b) Construction of Village Warehouses

Village warehouses will be constructed in the major villages of each development area,

in order to temporarily store the rice produced in the farms in the development area, to control the shipment of the vegetables and to improve the shipment efficiency. The storage and control will be only temporary, and the products will be sequentially delivered to the GVC union or transported to the market. Additionally, because the GVC organization activities increase as the production activities increase, a space to be used both as the GVC office and cargo collection will be constructed inside the village warehouse to provide for multiple purposes. Although there is no need to build a warehouse in M'Bahiakro development area where the already existing warehouse is used, warehouses will need to be constructed in the remaining four development areas.

These facilities will have a storage capacity of approximately 200t of unhusked rice, as specified below.

- Storage Capacity: 1.0t of unhusked rice takes up the space of 1.6m3. Therefore, the total volume = 1.6m3 x 200t = 320m3. Assuming the stack up is 4.0m high and the space loss is 10%, the area is to be approximately 90m2.
- Office: 15m2 is to be secured for the office. The required area, therefore, is 105m2 each.

5-9 Preliminary Design of Major Facilities

5-9-1 M'Bahiakro Area

(1) Low Dam

(a) Objective

As mentioned in Paragraph 4-9 of Chapter 4, the objective to construct the low dam is to make possible introduction of two cycles paddy by storing abundant rainy season river water in the minor bed of the N'zi river for dry season, and also to make water management easy by alleviating pumping head by raising the water level.

(b) Proposed Construction Site of the Dam.

The low dam is constructed at the adjacent site of No.5 Block.

(c) Design Flood Discharge

The design flood discharge for the low dam is set up to be 470 m^3/sec which is the 10 years return period probable discharge of exceedance. The design high water level of the stream side of the dam is set up to be 120.4 m which is the water level when the above-mentioned flood discharge flows over the dam which is in a deflated condition.

(d) Storage Capacity and Structure of the Dam

The full storage capacity is planned to be 2,760,000m³, which can satisfy the water requirement responding to the drought year of five years return period (nearly equivalent to the fourth drought year from 1973 ~ 1992) based on the water balance analysis of 20 years data from 1973 ~ 1992.

As stated in Paragraph 4-9 of Chapter 4, an inflatable rubber dam (or rubber dam for short) crested up by concrete dam is adopted. The rubber dam is a kind of inflatable weirs, and the inflation and deflation can be controlled by injecting air into the rubber bag. It is designed that the deflation is made automatically when discharge exceeding the design maximum overflow depth flows over the dam.

(e) Dimensions of the Dam

Dam height when inflated :	5.0 m	EL.118 m
(Concrete dam height :	2.0 m)	EL.115 m
(Rubber dam height :	3.0 m)	
Dam length	33.25 m x 2 spans	
Downstream apron width :	22.0 m	
Maximum apron thickness :	2.5 m	
Minimum apron thickness :	0.5 m	
Upstream horizontal cut-off width :	5.0 m	
Downstream riprap width :	14.0 m	

(f) Deflation Depth

The vibration of the rubber bag generated by greater overflow depth is designed to be mitigated by installing the rubber bag with a deflector. As the result, the maximum overflow depth soon before the deflation is designed to be 1.5 m which is half the height of the rubber dam. Then the discharge is 250 m^3/sec.

(g) Power Source

The blower to send air to the rubber bag is designed to be motor driven type, and its electricity is planned to be supplied by the substation of the No.2 zone pumping station.

(2) Intake Facilities

As the benefited cropland is located a few meters above ordinary water level of the N'Zi river and the riverbed gradient is as weak as 1/6500, gravity irrigation requires a quite long stretch of headrace to convey irrigation water and in consequence higher construction cost. Moreover, the operation & maintenance would be harder. For such reasons, a pumping irrigation method by means of submerged motor pumps is planned as mentioned in Paragraph 4-9 of Chapter 4.

The capacity of the pumps is as follows;

- No.1 Zone Pumping Station :
  9.87 m^3/min x 300 mm x 55 kw x 20 m x 380 V x 50 Hz x 2 sets

-No.2 Zone Pumping Station
  8.04 m^3/min x 300 mm x 45 kw x 20 m x 380 V x 50 Hz x 2 sets

(3) Layout of Irrigation & Drainage Canals

(a) Irrigation Canals

The irrigation canals are composed of both distribution canals lined with concrete and earth-made field canals. As the existing concrete lining canals are in good condition, they are utilised as distribution canal.

(b) Drainage Canals

The drainage canals are composed of both field drains collecting drainage water inside the irrigation blocks and block drains which are confluent canal of field drains. The block drains are also planned to have conveyance capacity of intercepting runoff water from the outer areas.

(4) On-farm Development

The standard size of the present field lots ranges from 20 a to 25 a on average. However, the land levelling error ranging from some 10 cm to 15 cm causes uneven growth of paddy and decrease of the production. As no on-farm road is provided in the area except main farm road, the transportation works is obstructed. Accordingly, the field lot adjustment works is consequently required. The main farm or inspection roads are paved

with laterite and the total width is designed to be 5 m. The on-farm roads are designed to be 4 m of width and just embanked road. The field canals & drains are constructed together with field lot adjustment works. Standard size of the field lots is planned to be 100 m x 30 m = 30 a taking into consideration both the introduction of hand tractors and the present field lot size.

(5) Summary of Major Facilities

The major proposed irrigation & drainage facilities planned in the M'Bahiakro area are as follows;

Low dam : 1 site
Pumping station : 2 sites
Pipeline : No.1 Zone 3000 m, No.2 Zone 2240 m
Feeder canal : 645 m
Distribution canal : 13155 m (6775 m)
Field canal : 24100 m (955 m)
Block drain : 15015 m
Field drain : 21990 m
Main farm road not attached to canals : 13760 m

( ) : use of existing facilities

5-9-2 Dam Irrigation Areas of Dienzou, Yanmon, Eholié and Atofou

(1) Dams

(a) Design Concept of Dams

The design concepts for each dam are in conformity with the results of soil mechanical & geological survey and field reconnaissance survey as mentioned below. Though each dam site has soil foundation, construction of higher dam is deemed to be hard. However, construction of such dam as the storage depth being some 10 m is deemed to be possible. An earth fill dam is more suitable than a concrete dam in case that soil foundation is founded. An earth fill dam is broadly classified in earth dam and rock fill dam. However, procurement of rock materials would be more costly as its hauling distance from the quarry sites is estimated at 50 km to 100 km. Accordingly, an earth dam of which most of borrow materials for the dike can be collected at the adjacent areas of the dam sites is adopted. The impervious zone of the dike is designed to be wider in order to reduce water leak through

both of the dike and the foundation, and in order to make the dike resistible against seepage failure. A hard laterite riprap is provided on the upstream slope of the dike to make it resist against waves. The minimum excavation depth of the foundation is to be 1 m, and a cut-off trench is excavated by some 4 m of depth from the actual ground level. The width of the cut-off trench is to be 4 m, and keeps nearly the same value of the depth of the full supply level

(b) Design Flood Discharge

The design flood discharge is estimated by " Formula of Gumbel Chow ", " Formula of Rziha ", " Formula of Mononobe" and " Rational Formula ", and 20 % up values of the calculation results are employed as shown below.

Design flood discharge of dam

unit : m^3/sec

	Return Period (years)		
Dam Site	1000	200	100
Dienzou	116	98	91
Yanmon	69	58	54
Eholie	114	97	89
Atofou	148	125	116

(c) Overflow Depth on Spillway

The overflow depth on the spillway is designed to be 1.0 m when the design flood discharge flows over the spillway.

(d) Crest Length of Spillway

The crest length of the spillway on 100 years return period design flood discharge for each dam is calculated as follows;

Crest length of spillway

Dienzou	Yanmon	Eholié	Atofou
43.5 m	26.0 m	42.5 m	55.5 m

For the reference, when 1000 years return period flood discharge flows over the

above-mentioned spillway, the overflow depth is estimated as follows;

Overflow depth on spillway on 1000 years return period

Dienzou	Yanmon	Eholié	Atofou
1.17 m	1.17 m	1.17 m	1.17 m

(e) Wave Height

The wave height above the reservoir surface induced by wind is estimated by S.M.B method and Saville method in accordance with the relationship between wind velocity and fetch on condition of the design flood water level, and also wave reflection and wave run-up height depending on the structural form of the dike slope. The design wind velocity is 20 m/sec.

Wave height induced by wind

Dam	Fetch	Riprap Slope	Earth Slope
Dienzou	2.2 km	0.45 m	1.45 m
Yanmon	2.6 km	0.50 m	1.50 m
Eholié	3.0 km	0.60 m	1.70 m
Atofou	3.6 km	0.70 m	1.80 m

According to the above results, a riprap slope is employed.

(f) Elevation of Dam

The elevation of the dams is determined as follows;

$$Hc = Hf + h + hw + 1 \quad (\text{when } hw \geq 1)$$

$$Hc = Hf + h + 2 \quad (\text{when } hw < 1)$$

where Hc : elevation of the dam crest (m)
Hf : full supply level (m)
h : design overflow depth of spillway (m)
hw : wind induced wave height above reservoir surface (m)

Height of Dams

unit : m

Dam	Hf	h	hw	FB *	Hc
Dienzou	98.0	1.0	0.45	2.0	101.0
Yanmon	125.0	1.0	0.50	2.0	128.0
Eholié	105.0	1.0	0.60	2.0	108.0
Atofou	101.2	1.0	0.70	2.0	104.2

* : FB means Free Board

(g) Dimensions of Dams and Reservoirs

The effective storage capacity is planned to be the maximum accumulated required storage volume based on the water balance analysis of 20 years data from 1973 ~ 1992 considering extremely unstable river run-off to be utilized.

The dimensions of the dams are as follows;

Dimensions of dams

Dam	Dienzou	Yanmon	Eholié	Atofou
Role of Dike	Main Dam	Main Dam	Main Dam	Main Dam
Riverbed Elevation (m)	91.4	116.4	96.7	91.5
Foundation Elevation (m)	87.3	112.4	92.5	87.4
Full Supply Level (m)	98.0	125.0	105.0	101.2
Crest Elevation (m)	101.0	128.0	108.0	104.2
Dam Height (m)	13.7	15.6	15.5	16.8
Dike Volume (10^3 m^3)	124.8	138.8	227.8	267.9
Crest Length of Spillway (m)	43.5	26.0	42.5	55.5
Crest Length of Dam (m)	740	640	990	950

The dimensions of the reservoirs are as follows;

Dimensions of Reservoirs

Dam	Dienzou	Yanmon	Eholié	Atofou
Active Storage Volume (MCM)	2.422	2.514	4.620	8.460
Dead Water Volume (MCM)	0.348	0.156	0.260	0.440
Total Storage Volume (MCM)	2.770	2.670	4.880	8.900
Design High Water Level (m)	99	126	106	102
Design Flood Discharge (m^3/sec)	91	54	89	116
Catchment Area (km^2)	87	39	65	110
Net Irrigation Area (ha)	78	56	91	165

(h) Intake Facilities

The irrigation water stored in the reservoir is taken by a drop inlet facility, and conducted by a conduit provided under the dike. The elevation of the drop inlet is designed to be 1.0 m above riverbed elevation. The irrigation water having higher flow energy is once dissipated by an impact box, and introduced into the irrigation canal. The elevation of the drop inlet is as follows;

Elevation of drop inlet

unit : m

Dam	Riverbed elevation.	Drop Inlet elevation
Dienzou	93.0	94.0
Yanmon	118.0	119.0
Eholié	97.0	98.0
Atofou	93.5	94.5

(i) Temporary Diversion Works

A temporary diversion works is designed to divert the flow running at the dam site during the construction period without obstructing the construction works. The temporary diversion works is composed of a half river section cofferdam and an open channel temporary drain. The temporary diversion works is designed to convey 10 years return period flood discharge.

(j) Treatment to Counter Foundation Seepage

A treatment to counter foundation seepage is determined in accordance with condition of the foundation. When soil foundation is found, a cut-off trench is provided, and when rock foundation is found, a grouting is provided.

(2) Irrigation & Drainage Facilities

(a) Irrigation System

A gravity irrigation system is employed. The irrigation water taken from the reservoir is diverted to each field canal through distribution canals lined with concrete, and distributed to each field lot. Taking into consideration efficient water management and transportation work, field canals are disposed together with on-farm roads at the interval of 200 m. The field canals are disposed at one side of the on-farm roads, and the irrigation water is distributed to both sides of the field lots of the on-farm roads through PVC pipes crossing the roads.

(b) Drainage System

- Inner Drainage

The drainage water from each field lot is introduced into the field drains, and drained out to the outer area through the trained river or the natural stream

- Outer Drainage

No larger tributary flowing into the benefiting area is found excluding the Eholié area. In the Eholié area, as a tributary called " Ninglinwa river " holds larger catchment area, an outer drainage system is planned.

(c) Irrigation Canal

The distribution canals are lined with concrete. The field canals are to be of earth. Inspection roads paved with laterite are provided along the distribution canals for the purpose of the efficient operation & maintenance.

(d) On-farm Development

Standard field lot size of the paddy field is designed to 100 m x 20 m = 20 a. 20 % of the total irrigation area is planned to be used for upland crops, however irrigated.

(e) Road Plan

Proposed roads are classified into access road linking villages with the croplands and farm road. The access roads are paved with laterite. As for the farm roads, the inspection roads along the distribution canals are paved with laterite, however the on-farm roads are to be embankment roads.

(f) River Training

At the present condition, the downstream courses of the present rivers after the proposed dam sites are meandering complicatedly. The cross section of the water courses is very narrow and overgrown. During flood some parts of croplands as well as the major bed of the rivers are inundated, however the flow velocity is deemed to be low. The river training is planned together with the on-farm development. The trained cross section is designed to convey 10 years return period flood discharge considering the storage effect of the dam reservoirs.

(g) Fish Pond

Fish ponds are constructed by excavating some field lots deeper. The water for pisciculture is provided from the distribution canal. The standard size of one pond is planned to be 20 m x 15 m = 300 m^2, and by excavating one 20 a size field lot

(3) Summary of Major Facilities

The major proposed irrigation & drainage facilities for the tributary dam irrigation areas are as follows;

Proposed Facilities	Dienzou	Yanmon	Eholie	Atofou
Distribution Canal (m)	5030	4010	4525	8420
Field Canal (m)	4365	3285	5640	9700
River Training (m)	4475	4250	2560	4500
Field Drain (m)	3440	3250	5700	9570
Additional Farm Road (m)	1670	285	1910	800

(4) Construction Materials (Dam Embankment Materials and Concrete Aggregate)

(a) Impervious Materials for Dam

According to the ivorian side counterpart engineers, weathered laterite rather than silt and loam is generally employed for core materials of lower dam in Côte d'Ivoire. As the proposed dam height is low, the materials with low permeability, even if the compression index is greater, can be employed. Accordingly, the core materials are collected at the adjacent areas of the proposed dam sites.

(b) Riprap Materials

- Hard Laterite

In Côte d'Ivoire hard laterite is often employed as riprap material for low dams. Accordingly, hard laterite is employed as riprap material for the proposed dams, too. According to the counterpart engineers, hard laterite can be collected in the savannah area located in the N'zi river right bank. However, the hauling distance would be longer.

(c) Filter Materials

- Coarse Materials

Quartz gravel scattered in the lower terrace of the N'zi river is used. According to the reconnaissance survey, such quartz gravel can be collected in Yerakro village located in Department of M'Bahiakro, Soh-Nguessankro village and Ebimlossou village.located in Department of Dimbokro and Akobakabo village located in Department of Bongouanou.

- Fine Materials

Sand scattered in the lower terrace of the N'Zi River is used. According to the reconnaissance survey, such sand can be collected in Koffiyaokro village located in Department of M'Bahiakro, Taniakro village and Ebimlossou village located in Dimbokro and Fronobo village located in Bongouanou.

(d) Concrete Aggregate

- Coarse Aggregate

Screened and washed quartz gravel collected in the above-mentioned lower terrace is used as coarse concrete aggregate for the general structures such as irrigation canals and related structures. The crushed granite procured in Boli Village is employed for the important structures requiring high strength such as the conduit of the dam intake facilities, the concrete dam and the apron for the low dam of the N'zi river.

- Fine Aggregate

High quality sand scattered in the lower terrace of the N'zi river is employed as fine concrete aggregate. Such sand can be collected in the same sites as the above-mentioned for filter fine materials.

(c) Condition of Collection Site of Materials

- Yerakro Village

Deposition thickness of quartz gravel ranges from some 1 m to 1.5 m, and small quantity is utilised for construction materials in M'Bahiakro. The grain size is 40 mm or 30 mm or less.

- Soh-Nguessankro Village

The collection site is located about 300 m east away from the national road. At the construction of the national road around Bocanda, a screening and washing machine for concrete aggregate for the bridges and asphalt aggregate for the road pavement was installed. Deposition thickness of the quartz granite ranges from some 1.5 m to 2 m. The grain size is 40 mm or 30 mm or less. Top soil layer covering granite layer is not thick.

- Ebimolossou Village

The collection site for sand is scattered at right side of the road running inside Sanuan classified forest. The sand layer is covered with top soil layer having some 2 m of thickness. The deposition thickness of sand is some 1 m to 1.5 m. The texture is fine and single-grain sized. Silt or laterite layer is found under the sand layer. A large number of collection points have been almost exhausted, therefore the extensive area would be needed to supply the required quantity. Coarse aggregate is scattered at left side of the road, and the nature is quartz granite. The deposition thickness is from some 1 m to 1.4 m. Silt layer is found under that layer. The collection sites for sand and gravel are located about 5 km away from the national road, and moreover 2 existing timber bridges in the way should be