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Nam Theun DAM – NTPC Project

Morphopedological and agronomic appraisal in the resettlement zone for the farmers of Nakai plateau (Laos)

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I. *INTRODUCTION*

The mission took place from **8 to 18 May 2005**. Financed by AFD, it was requested by the Laotian Ministry of Industry, NTPC and AFD. It was conducted within the framework of the coming **resettlement of farmers** whose present land on Nakai Plateau will be flooded by water impounded by the Nam Theun dam at the end of 2009.

The aim of the mission performed by **Patrick Julien** (independent consultant) and **Michel Raunet** (CIRAD) and **Somchanh Syphanravong** (PRONAE) was to perform a **pedological and agronomic evaluation** of the 20,000-hectares region to be allocated for use by migrants settling in 17 new villages (1,100 families) on the western edge of Nakai Plain. **Draft scheduling** of **DMC agro-ecological** systems was also performed (at NTPC's request). This report on the mission is accompanied by a **morphopedological map** making it possible to reason in relation to village land areas.

We are most grateful to the NTPC team in Vientiane and Oudoumsouk (Nakai) for their interest and for the extremely efficient help that they provided. Our thanks also go, of course, to the AFD agency in Vientiane and to PRONAE for the preparation and hosting of the mission.

We would like to thank particularly Florent Tivet (CIRAD) who was in charge of the good coordination of this mission with all the partners and who helped defining the terms of reference with NTPC and AFD (identification mission, September 2004).

II. *THE PHYSICAL ENVIRONMENT*

1. Climatic data

Nakai Plateau is exposed to the monsoon from the south-west and has some of the highest rainfall in Laos, with annual average annual precipitation of between 2500 and 3000 mm. Rainfall distribution is unimodal (one rainy season). The dry season is from 15 October to 15 March. December and January are the two driest months and July and August are the wettest (rainfall may exceed 750 mm per month).
The average annual temperature is 22.6°C. The hottest period is from March to July and the coolest period is in the dry season from December to February. The maximum temperature is 36.5°C in April and the minimum is 2°C in December.

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mean Rainfall	9.9	17.3	59.6	140.0	389.8	438.8	763.7	619.5	390.0	85.1	13.1	7.2	2979.0
Relative humidity (%)	63	64	65	60	78	86	89	87	83	79	79	68	75
Mean temperature (%)	17.3	19.7	23	26.1	25.5	25	24.7	24.4	24.5	24.2	19.4	17.9	22.6
Mean Max. temperature (%)	25.1	27.6	29.9	33.0	29.8	28.3	27.5	27.7	28.3	28.9	25.4	24.7	33.0
Mean Min. temperature (%)	9.6	11.8	16.0	19.2	21.1	21.7	21.8	21.1	20.7	19.5	13.4	11.2	9.6
Extreme max temperature (°C)	31.2	31.0	34.9	36.5	35.0	30.6	30.5	31.8	31.4	31.8	30.7	30.0	36.5
extreme min temperature (°C)	4.0	7.4	10.5	15.0	19.0	20.0	19.6	19.4	19.0	16.2	7.2	2.0	2.0
Evaporation class A pan (mm)	166	159	182	198	122	116	93	111	128	159	161	141	1735
Evaporation from open water (mm)	133	127	146	158	98	93	75	89	102	127	128	113	1388

Climatic data for Nakai Tai (1994-2002)

2. Geology

Nakai 'Plateau', that is to say Nam Theun plain and its hilly or mountainous edges lies on a perched syncline (elevation 525 to 580 metres) consisting of mid-Jurassic to early Cretaceous continental sandstone. The centre of the syncline is roughly in the position of the centre of the plain/depression.

The dips of the beds follow the average topography of the edges of the plain.

The facies of the fine-grained sandstone varies in colour (beige to wine red), texture (sand, clayey sand, conglomerate), in degree of consolidation and in stratification thickness. Interstratification with violet clayey-schistose material is frequent.

The sandstone syncline terminates and is crossed to the south by a tall, long scarp with a 200 to 500 metres difference in elevation that dominates Lower Jurassic schistose and Palaeozoic karsts. The syncline ends in the north in a vast panel (with shapes like smoothing irons) cut by the drainage pattern of the Nam Theun system.

More recently (end of the Tertiary/beginning of the Quaternary), the Nakai syncline underwent tectonic readjustments along the main axis of the syncline, that is to say NW-SE. The edges of the depression are thus two sub-parallel faults. Two other major faults to the south and the north are further from the depression but lie in the same direction and separate the hill features from the mountain features, the latter being in a dominant position.

Nakai Plain-Plateau is thus similar to a “graben” that probably led to its filling with a substantial depth of fluvial and/or fluvio-lacustrine alluvium, with various terraces.

3. Geomorphology

3.1. The plain

The plain lies NW-SE and is 3 to 6 km wide and 38 km long. The rivers Nam On and Nam Theun display broad meanders with down-cutting of up to 10 metres. The average longitudinal slope is extremely small (0.2‰) and so flows are very slow, accounting for the size of the flood zones. The morphology of the plain displays four major sets of alluvial forms in which clay is dominant:

- ***An upper alluvial terrace*** (red, “ferrallitised”), 10 to 20 metres above the present alluvial level. This terrace is found mainly in the north in the extreme downstream part of the plain (covered with dense secondary forest) and along almost the whole of the southern edge of the plain, where is lies on weathered sandstone material.

- ***A mid alluvial terrace***, with brownish yellow soils at the start of “ferrallitisation” and perched 5 to 10 metres above the present alluvial level. This terrace is particularly marled in the downstream third of the plain.

- ***A non-floodable present alluvial level*** at an elevation of between 526 metres (in the downstream part of the plain) and 533 metres (upstream). This consists of alluvial forms with external drainage (including numerous micaceous bank ridges).

- ***A present floodable alluvial level*** at an elevation of 524 metres downstream and 529 upstream. It consists of decantation basins and blind valleys (between the upper and medium level terraces) filled by overflows and the inflow of large and small watercourses that shift and flow episodically for lack of sufficient slope and/or outfalls. Some parts of these basins can form permanent ponds.

3.2. The hilly or mountainous southern edge of the plain

The whole of this region running to the large western scarp will be used as land for the resettled villages. A large NW-SE fault divides the zone into two vast units.

- ***In the west***: mountainous relief with very encased valleys with no valley-bottoms. The cover is dense natural forest, much of which is doubtless primary forest. Slopes are steep at between 10% and 50%.

- ***In the east***: the hill and plateau relief is cut by a drainage pattern with valley-bottoms (that is to say filled with colluvium and alluvium) with secondary forest cover (resulting from slash and burn cultivation). These hills and plateaux usable for the future village land form a zone lying between the plain-depression and the large fault; the zone is 42 km long and from 1.5 km wide (in the north) to 4.5 km in the south. The zone has four sub-components:

  - **Old alluvial terrace**

    This is at the edge of the plain in a dominant position at an elevation of 540-550 metres. These broad (about 1 km) alluvial remnants are omnipresent in the northern two-thirds of the perimeter and disappear in the southern third. The terrace is divided into blocks, strips and panels by a drainage system with hydromorphic, floodable valley-bottoms encased at a depth of 10 to 20 metres. The terraces were initially flat but have now acquired convex hill and plateau forms with slopes not exceeding 10%.
    The alluvial materials are clayey, 2 to 5 metres thick, very weathered ("ferrallitised") with the initial bedding broken down and lying on a thick foundation of rolled pebbles on sandy weathered material.
    The deep, reddish-orange soils (see below) are "ferrallitic" according to the traditional French classification and have been renamed 'ferralsoils' and 'acrisoils' in the FAO reference list. They are generally covered by fine secondary forest vegetation (regrowth of old fallows).

  - **Valley-sides on weathered sandstone**

    These are connecting slopes between the highest sandstone plateaux (see below) and the 'humid' valley-bottoms that drains the landscape. The slopes range from 5 to 15%. They are covered with weathered sandstone regolith several metres thick. As with the old terraces, this weathered material is ferrallitic (ferralsoils and "acrisoils" in FAO terminology).

  - **Sandstone plateaux**

    This is the dominant surface type, at an elevation of 545-560 metres. The plateaux, particularly marked in the southern half and the centre, are divided by a network of encased (5 to 20 metres) valley-bottoms. The slopes are small at 0 to 5%. The main slope of the plateaux is the same as that of the dip of the sandstone sedimentary beds.
    The vegetation features pines with grassy underwood, sparse short deciduous trees and slow regrowth of slash and burn performed at various times in the past. Slash

and burn regrowth of the same age is much more dense on the old terraces with deep soil than on these plateaux where the soil is mediocre.
Furthermore, a feature (indicator) of the surface of the plateaux is large whitish bare patches of silt (fine sand) showing intense sheet erosion. These plateaux have the most unfavourable soils in the region and form the greater part of the land (see below). The more or less weathered sandstone base is at a depth of 30 to 100 cm. FAO classifies these soils as acrisoils.

- **Valley-bottoms**

These small valleys cut into hills and plateaux in a "reindeer antler" pattern. The small valleys are flat or concave and 20 to 200 metres wide. When the bottomland is not flooded, the groundwater is close to the surface, resulting in the formation of hydromorphic soils ("gleysoils") that are beige (moist state) to whitish (dry state) on thick colluvium-alluvium.
Most of these valleys-bottoms run into Nam Theun plain but in the south they are tributaries of the Nam Kathang Gnai that flows westward towards the large scarp in markedly encased meanders in the sandstone. This drainage direction appears to be opposite to the direction of the dip of the sandstone. This is remarkable and quite curious, as if tectonics had reversed (westward) the initial dip of the vast panel forming the south of the sandstone syncline.

4. Morphopedology

The characteristics and quality of soils, their distribution and the bio-geochemical processes that take place in them are the result of interactions and retroactions between geological and geomorphological features, the evolution of the landform, the nature of the parent materials, drainage and sometimes plant cover, etc.
This is why it is more appropriate to reason—spatially and at process level—in terms of 'morphopedology' and not simply 'pedology'.

The morphopedological units are described in large zones:

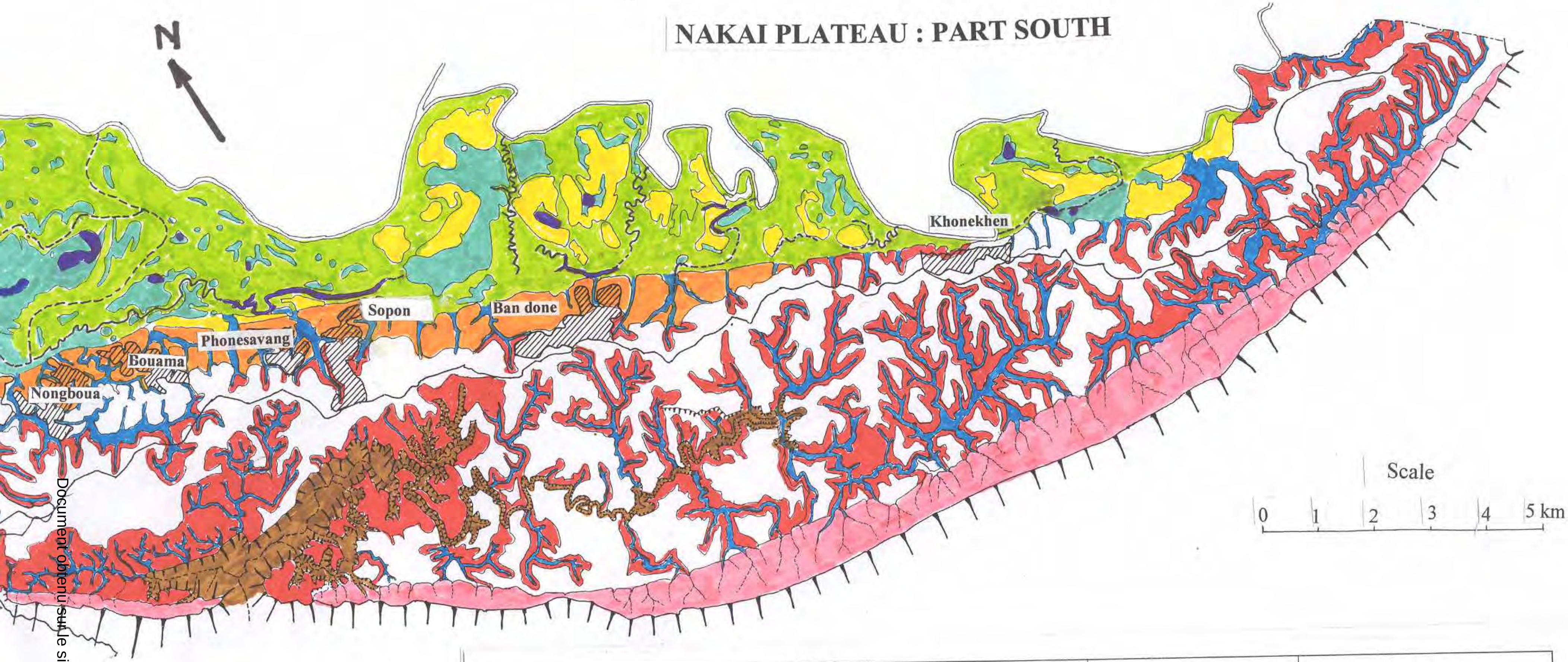
- **the 'high' zones** (where the new village land is to be) to the west of the alluvial plains.
- **the 'low' zones (alluvial plains).** These will be flooded by the impounded water from the end of 2009.

4.1. The high zones

4.1.1. Rocky scarps

These consist of the major scarp (200 to 500 metres high) that bounds the region to the west and the steep slopes of the river Nam Kathang Gnai that has cut through the sandstone strata to a depth of from 20 metres (mid-course) to 200 metres (downstream course).

NAKAI PLATEAU : PART SOUTH



	LANDFORM	PARENT MATERIAL	DRAINAGE	VEGETATION	SOILS
(brown)	***Rocky escarpments***	Sandstones	Very good	*Forest*	**Sandstone** outcroppings
(pink)	***Dissected broken mountains (slope : 20-50%)***		Very good	*Dry evergreen and mixed deciduous forest*	Deep **Acrisoils** and **ferralsoils**
(red)	***Hilly Valley – sides (slopes: 5-20%)***		Good	*Forest or shrub*	Silty-clayey **acrisoils**
(white)	***Undulated Plateaux (slopes : 0-5%)***		Temporary hypodermic perched water-table	*Shrubby broadleaf fallow and pines*	Shallow, silty-loamy, albic, stagnic, **Acrisoils**
(blue)	***Valley-bottoms***		Very poor	*Riparian*	Clayey **gleysoils**
(orange)	***High-terrace***	Old alluvium	Good	*Forest fallow*	Deep **acrisoils**
(yellow)	***Mid-terrace***	Recent alluvium	Good to medium	*Forest / shrub fallow*	Deep brown **fluvisoils**
(green)	***Non-floodable plains***	Present alluvium	Medium to poor	*Shrubby herbaceous savanna*	Deep gleyic **fluvisoils**
(turquoise)	***Floodable plains***		Poor	*Herbaceous savanna*	Deep **gleysoils**
(purple)	***Inundated basins***		Permanent water	*swamp*	**water**

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Juin 2005
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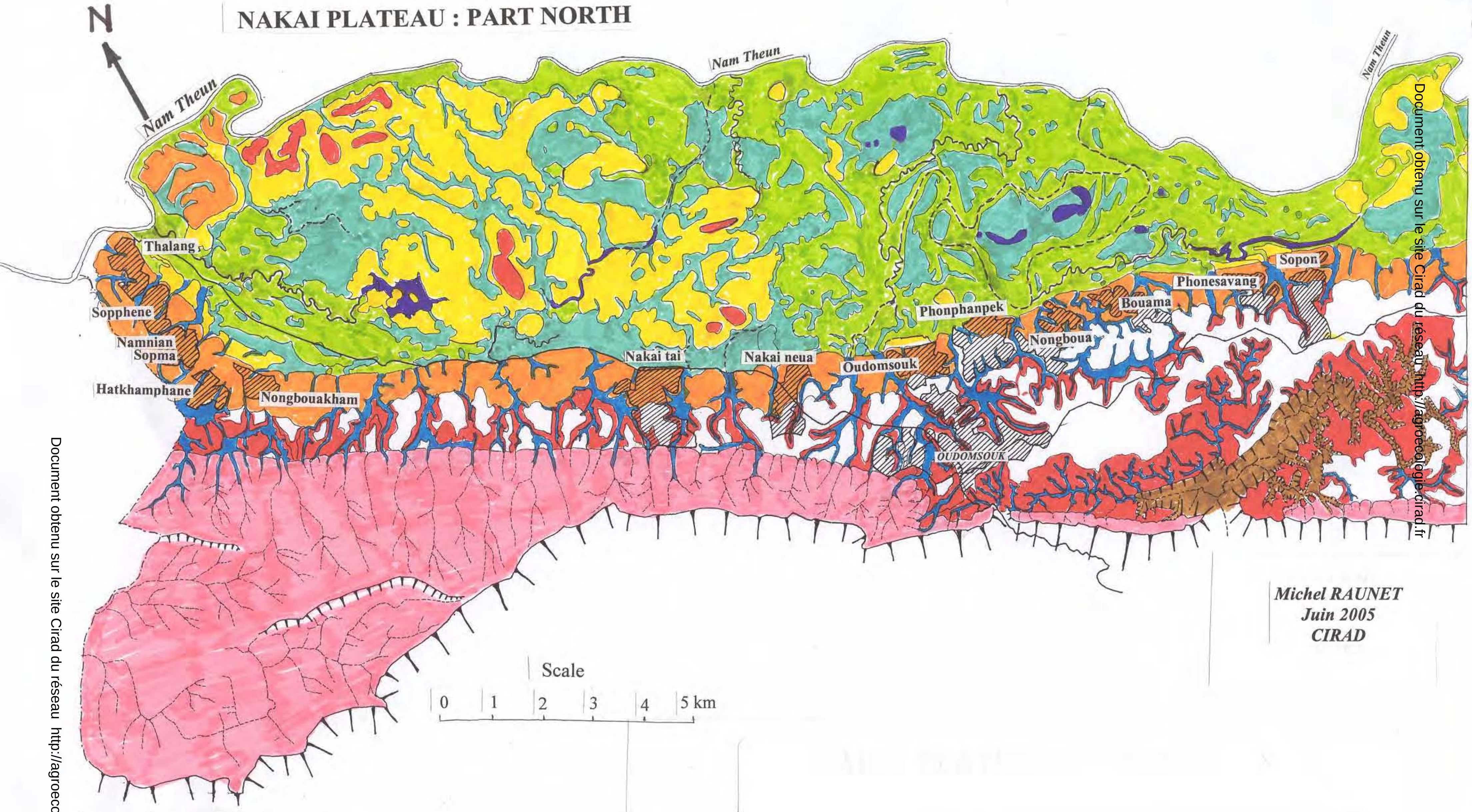
NAKAI PLATEAU : PART NORTH



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NAKAI PLATEAU (RDP LAO)

RECONNAISSANCE MORPHO-PEDOLOGICAL MAP

4.1.2. Mountainous slopes on sandstone

The large unit is the land upstream (to the west) of the large fault, consisting mainly of the Sayphou Ak forest zone. This is the largest such zone in the north (up to 6 kilometres). It forms a fairly narrow chain less than a kilometre wide in the south.
The dense forest areas (primary forest?) are very difficult to enter. The slopes are very steep (20 to 50%) and they have a dense, encased drainage network (30 to 120 metres between valleys and crests).
In spite of the steep slopes, the mountain forest soils are often deep as they have become polyphase through the morphodynamic disturbance (mass movements, colluvium, etc.) of weathered ferrallitic material.
Soils are dark red, brownish red or brownish yellow. They are acid (pH 4.7 to 5.2), silty-sandy to silty-sandy-loamy and well drained; soil structure is fairly good, as is the organic matter content (2 to 4% to a depth of 20 cm).
Historically, these forests were doubtless little subjected to slash and burn and it can be supposed that they are fairly close to their 'primary' state. They are rich in plant and animal resources for gathering and hunting.

4.1.3. Hill slopes (valley sides) on sandstone

These morphopedological units form the links between 'plateaux' (see below) and valley-bottoms. Slopes range from 5 to 20% and are generally between 10 and 12%. They are thus not incompatible with DMC type farming (Direct seeding Mulch-based Cropping systems) with little or no tillage.
The forest vegetation found on this land has been 'degraded' by many slash and burn operations.
The soil is generally a brighter colour (brownish red to brownish yellow), deeper (60 to 150 cm), better structured less sandy at the surface (15 to 25% clay) and better drained than the plateau soils. However, they are just as acid (pH 4.5 to 5), have an extremely low organic matter content and are short in exchangeable bases and assimilable phosphorus.

4.1.4. 'Plateaux' on sandstone

The soils of these units are the commonest in the 'high', non-mountainous region, forming about 50% of the land, that is to say some 4,000 ha. This is also the most unsuitable land for farming, except for the scarps and valley-bottoms.
The overall slope of the plateaux matches the sub-horizontal dip of the sandstone beds. The slopes are small and often less than 5%.
At a depth (deeper than 10 to 100 cm), the weathered sandstone still roughly displays the dip, that forms **an obstacle to the rapid infiltration of rain water** and affects the 'atmosphere' and bio-geo-chemical processes that govern soil formation.
The clearest indicators for easy identification of this type of soil are firstly **the presence of pines** in the degraded low forest vegetation with low density of deciduous trees, and secondly the presence, underneath, of large patches of white silt (fine sand) spread by runoff.
These zones are fallows that follow slash and burn farming and where secondary forest develops much more slowly than elsewhere, with the growth of large pines.

The plateau soils have a **shallow usable root depth** (20 to 60 cm) because of the presence of compact weathered sandstone that cannot be used by roots and that means that this land has low permeability.

- **The characteristic profile** of this land is as follows:

- **0-8 cm:** pale grey (when dry) to dark grey (when moist), friable but not structured (absence of grumous, granular or polyhedral structure in spite of the presence of numerous roots. Numerous charcoal fragments, silty-sandy texture: 9% clay (0-2 µ), 29% loam and silt (2-50 µ), 62% sand (50-2000µ).

- **8-30 cm:** pale beige (dry) to yellow (moist), seeming to have been bleached and washed in comparison with the underlying and overlying horizons. Rusty patches (signs of temporary hydromorphy). Continuous solid structure. Compact when dry. A few roots. Pieces of charcoal. Silty-sandy texture. Approximately 15% clay (0-2 µ), 29% loam and silt (2-50 µ), 55% sand (50-2000 µ), especially fine sand.

- **30-60 cm:** overall ochre-yellow horizon displaying rusty ferruginous patches (hydromorphy) or reddish patches that are firmer and sometimes indurated. No structure (continuous appearance) and very compact when dry. Some charcoal debris is present, indicating old slash and burn operations. Silty-loamy texture with approximately 22% clay (0-2 µ), 27% loam and silt (2-50 µ) and 51% sand (50-2000 µ), with fine sand dominant.

- **Deeper than 60 cm:** very compact horizon. Weathered sandstone. Sandstone strata or small plates still visible. Mottling with large patches of beige, yellow, ochre, wine red and white. Some release of nodules or ferruginous gravel. With very low permeability, these materials cannot be penetrated by roots.

- **Analytical characteristics** (see table).

  - **The grain-size distribution** of these soils reflects that of the sandy substratum that is very rich in fine quartz sand (50-200µ). These soils display the results of a **leaching process** with, downwards in the profile, a increase in clay and, in contrast, a comparative decrease in fine sand. The proportions of fine and coarse silt are practically unchanged.

Depth (cm)	Grain-size distribution (%)					Organic matter		pH water	Phosphorus (ppm)		Exchangeable bases (me100g)				S	TS	Al^{+++}	CEC	Al/ CEC
	C 0-2µ	FL 2-20µ	CL 20-50µ	FS 50-200µ	CS 200-2000µ	(%)	C/N		Tot.	Avail.	Ca	Mg	K	Na	me 100g	%	me 100g	me 100g	%
0-10	9	9	20	57	5	2.55	19	4.9	108	2.97	0.28	0.19	0.1	0.033	0.6	31.4	1	2.04	49.4
10-30	15	9	20	51	5	0.73	14.4	4.78	88	1.91	0.1	0.11	0.074	0.019	0.3	12.0	1.6	2.4	66.8
30-60	22	10	17	43	8	0.6	12.2	4.79	81	1.72	0.06	0.09	0.085	0.022	0.25	7.0	2.7	3.4	72.5

CIRAD Laboratory Montpellier

Mean analytic data for shallow, silty-loamy albic stagnic acrisoils

- **The organic content** is small. The upper horizon (0 to 8/10 cm) contains 2 to 3.5% organic matter (average 2.55%). The figure falls to 0.6% at 50 cm. It is observed that the C:N ratio is abnormally high (15 to 25). This is probably the result of a comparative abundance of charcoal debris left by slash and burn operations. **The organic matter is extremely fragile** as it is loosely bonded to the sandy mineral skeleton.

- **Phosphorus content**

The analyses reveal very low values, with about 100 mg/kg total phosphorus at the surface and less than 3 mg/kg assimilable phosphorus (Olsen). All these soils display **an extremely marked shortage of phosphorus**.

- **pH**

The soils are very acid with a pH of some 4.9 (4.7 to 5) at the surface and 4.8 at a depth. This is related to the very poor exchange complex and soil leaching. Numerous nutritional imbalances or deficits and aluminium toxicity are therefore to be feared. Some crops such as maize do not accept such acidity.

- **Exchange complex**

The exchange complex is also very poor with cation exchange capacity (CEC) of some 2 me/100g at the surface and about 3 me/100g at a depth. This is related to the intense leaching of colloids from the soils, their perched groundwater (hypodermic) hydrological regime with lateral flows during rainy periods. Total exchangeable bases is very small of course at 0.60 me/100g at the surface and 0.25 me/100g at a depth. The saturation percentages are 30% at the surface and 7% at a depth. The deficits in calcium, magnesium and potassium are thus very marked.

- **Exchangeable aluminium**

Large quantities of aluminium ions are found in the base exchange complex (1 me/100g at the surface and 2.7 me/100g at a depth). The Al:CEC ratio is very high at 50 to 73%, confirming that these soils display serious aluminium toxicity.

- **Soil formation conditions**

These 'acrisols' (FAO classification) or 'leached podsolic ferrallitic ' (French classification) formed on weathered sandstone. Sound sandstone is not generally observable except at the bases of quarries. The stratification dip is sub-horizontal, slowing the deepening of loose soil. It is difficult for rain water to infiltrate to depths greater than 60 cm. This means that the soil is waterlogged practically to the surface during severe rainy periods. Waterlogging is not stagnant. The small groundwater store accumulated flows laterally (subsurface runoff), with a strong colloid leaching effect and hence a reduction of minerals. This results in a reducing geochemical ambiance at certain times during the rainy season.
Processes like this result in leached, sandy bleached soil that is extremely poor.
This hydrological regime is fairly unfavourable for cultivated plants, forage plants and perennial crops.
Organic matter forms films and coatings with little adherence to mineral materials consisting of quartzy silt (fine sand and coarse silt). Very little structured and very labile, this clayey-humus complex breaks down rapidly when tilled and if it is exposed to rainfall. The organic matter is then easily washed out by runoff. The sand is heavier and remains spread on the surface in large whitish patches that characterise these extremely fragile soils.

It would seem essential to conserve existing organic matter and increase its proportion by DMC type practices in order to maintain soil fertility.
The vegetation observed in these shallow 'leached hydromorphic acrisols' reveals their poor quality. More large pines are observed on this type of land than elsewhere and these release pine needle litter that contributes further to soil acidification.
The broadleaved forest vegetation is small and often thin.
As elsewhere, the land has been used for slash and burn cultivation in the past (shown by the presence of charcoal throughout the soil). But forest regrowth is poor here, however long the fallow.

4.1.5. The high terraces

The remaining approximately 1,700 hectares of high alluvial terrace consists of a string of high areas cut by valley-bottoms running down in the plain/depression. They are about 1 km wide and set between the recent alluvial plain that they dominate distinctly and the sandstone plateaux described above. Only the southern part of the perimeter does not display this feature and the leached soil plateaux adjoin the plain directly.

The fragments of the upper terraces display sub-horizontal to convex topography fairly similar to that of the preceding plateaux. For this reason it is sometimes difficult to distinguish between the surfaces of the two morphopedological units.

The features distinguishing these soils from the former are their **thickness** (greater), **texture** (less sandy), **consistency** (less compact) and often their **organic matter content** (greater). Furthermore, the natural vegetation consists of taller, denser forest regrowth than that of the plateaux and there are fewer pines.

Grain-size distribution displays about 30% clay throughout the profile (from the surface downwards), 11 to 22% loam and 20 to 50% sand.

Average **organic matter** contents are as follows:

- 0-10 cm: 4.8% (C/N = 13 to 14)
- 10-30 cm: 2.5% (C/N = 14)
- 30-60 cm: 1.4% (C/N = 15)

These (forest) soils thus have a fairly high level of organic matter well bonded to colloids. This gives them better structural stability than that of the plateau soils.

With regard to their chemistry, the terrace soils contain 230 mg/kg total phosphorus in the 0-10 cm depth and 3 to 6 mg/kg assimilable phosphorus (Olsen). **This is a little better than the plateau** soils but the levels are still very low, with the soils displaying a phosphorus deficit.

These soils are always hyperacid (pH 4.3 to 4.5 at the surface and 4.5 to 4.7 below). This carries a strong risk of aluminium toxicity, with a Al:CEC ratio of between 65 and 75%.

The exchange capacity is still small (approximately 2 me/100g throughout the profile) in spite of a larger proportion of colloids (clay and organic matter). This means that these soils—

subjected to annual rainfall of nearly 3 metres—are thoroughly lixiviated (impoverished) by infiltration. The process is enhanced by the roots of the forest vegetation in spite of the rise in bases by leaf litter.

To sum up, the soils of the high terraces are always extremely poor and acid with regard to their chemistry. In contrast, the thickness, texture, structure and drainage are favourable and potentially enable good crop root growth. We have seen above that these qualities are absent from the acrisols on the sandstone plateaux.

4.1.6. valley-bottoms

This is mentioned for reference. The land consists of hydromorphic soil on alluvium and colluvium that thicken at the valley-bottoms. Most of this land and the base of the slopes leading to it will be flooded by the reservoir.

4.2. Low zones (alluvial plains)

Although the impounded water will flood most of this plain (with the exception of a few isolated sandstone hills downstream), covering about 40,000 hectares, a few comments on the morphopedological characteristics are made here.

The “graben” is occupied by the Nam On and Nam Theun drainage systems.
As has been seen, the morphopedological units of this river system comprise **'old' formations** (terraces) and **'contemporary' units** (topography of the present base level).

4.2.1. High terrace

Broad sections of this are found in the far north of the plain (north of the village of Thalang) and their pedological features have been described. They are covered by forest.

4.2.2. Medium terrace

Much of this is found in the downstream and upstream thirds of the plain. The soils are in the process of “ferrallitisation”, that is to say that the original alluvial clay has not been fully weathered or leached. They are still classified as '**fluvisoils**' (FAO classification) and not yet 'ferralsoils' and less still 'acrisoils'. They are yellowish brown, have a balanced texture (about 30% clay) and are deep, well-structured, drain well, have a high organic content (thanks to good forest vegetation) and are chemically advantageous. The loss of these soils generally used for rice after clearing by slash and burn will be a marked feature for the farmers in the plain.

4.2.3. The non-floodable base level

This level covers about half of the plain (in any case on the left bank of the Nam Theun and the Nam On).
A large part of these zones is currently used for lowland rice (rainfed aquatic rice that is not irrigated). The alluvial system there is more or less abandoned (or only functions sporadically) by the distributaries or tributaries of the 2 main rivers, with former riverbanks, former river beds (with sand and mica) with numerous meanders, filled in former settlement depressions (more clayey), etc.

These soils (**gleyic fluvisoils**) have **excellent physical qualities.** They are deep, have a balanced grain-size distribution (30% clay, 45% loam, 25% sand), and are rich in organic matter, with 5% at a depth of 60 cm. However, internal drainage can be slow in the rainy season with a groundwater level that may rise sporadically (some zones may be flooded occasionally).

With regard to chemistry, the pH is some 5 to 5.4 at the surface and slightly less than 5 below. Total phosphorus is a little better than that of the other soils, with 450 mg/kg in the top 20 cm. Assimilable phosphorus is still low at 2.5 to 6 mg/kg in the first 20 cm.

However, in spite of everything the exchange complex is not much better than that of the other soils. The Al/CEC ratio is always high (62 to 65%).

These soils are excellent for 'rainfed/groundwater' rice growing in enclosed blocks as they retain the water well. Of course, the farmers will not find the equivalent in the resettlement land.

4.2.4. The floodable base level

Forming 1/4 to 1/3 of the area of the plain, this consists of all the depressions and dead ends with no outfalls and clay settlement where water overspilling from rivers, distributaries, tributaries, valley-bottoms outfalls, etc.), rainwater and rising groundwater collects and stagnates. Water remains there during the rainy season and fairly late into the dry season. This level consists of the first zones that will be flooded by the reservoir.

The soils there are generally very clayey and grey or mottled (waterlogged with no aeration).

5. The agronomic consequences

The soils in the western part of Nakai plain-depression display the following main constraints:

- **extremely limited fertility**;
- **low organic matter content;**.
- this low 'fertility' is **concentrated in the upper 10 cm** of the soils ('organic' horizon);
- these soils should therefore be **disturbed as little as possible** in order to conserve this slender advantage: no burning of vegetation, no clearing with a bulldozer, no tillage and, in principle, no scraping to level the land into terraces;
- the agronomic practices used should aim at **increasing the organic matter content** (forage mulches, crop residues, clearing prunings returned to the soil without being burned, etc.);
- the soils are **extremely susceptible to erosion** (no structure, silty-sandy texture). They should therefore be covered all the time so that they are protected from attack by rainfall. Well-covered soils, even on slopes (up to 25%), do not require other erosion control measures (terraces, cordons, etc.);
- the soils **filter well** and have a **low water retention capacity** (shallow, silty-sandy texture). Developed as terraces, they would not easily retain hold water for lowland rice. Furthermore, without agroecological management (DMC), rainfed crops (rice, maize, etc.) will be **susceptible to drought** when it has not rained for more than 5 days;
- **calcium-magnesium and phosphate amendments** (thermophosphates in the latter case) must be applied to these 'empty', very acid soils; these are easy to obtain (in Vietnam or Laos) and are not expensive.
- **nitrogen fertiliser must be applied in split doses** to reduce the strong risk of leaching;
- **episodic hydromorphy** (waterlogging) favours the development of pests, weeds *(Imperata, Cyperus,* etc.) and diseases (fungi, bacterial diseases and virus infections).

III. *PROBLEMATICS OF THE ZONE – ACTIONS TO BE UNDERTAKEN*

Today, the farms of the 1,100 families concerned are firmly settled on the best land in the alluvial plain and this will be flooded. A total of about 40,000 of the 60,000 hectares of the agro-ecological area of Nakai plateau will be submerged. Farming systems have remained traditional. “Slash and burn” agriculture is used on soil that is capable of returning rapidly for forest fallow. Fallows are long at 10 to 15 years and ensure good productivity when the land is farmed again. Farming systems are centred on upland rice that covers the food requirements of families.

The 20,000 ha resettlement zone (with more fragile soils) has hitherto been used for forest resources, forest by-products and as rangeland for livestock.
In comparison with the other mountain regions of Laos concerned by slash and burn, it can be said that the shifting slash and burn agrarian systems of Nakai plateau were sustainable.

The re-installation of the villages on the 20,000 ha studied will not allow the sustainability of these traditional farming systems.

New 'more intensive' farming systems must therefore be envisaged that are capable of reproducing present forest agro-ecosystems over very short periods.
The problematics of settling agriculture in sustainable farming systems on this land, much of which is very fragile and degraded, resides in the capacity of these systems to replenish the soil continuously with organic matter in order to maintain productivity.

The cropping systems must therefore be covered at all times by live or dead mulch as soon as the forest or grassy cover has been cleared. This must be done even before the start of cultivation in order to regenerate the most degraded soils.

Cover consisting of **forage species** suited to the zone will play the same fertility regeneration role as forest cover but with much shorter fallows (3 years).

Forage fallows are an integral part of the farming systems and a component of the rotation. They can be used (mown) from the second year for partial use as cattle feed.

The National Agro-Ecology Programme (PRONAE) that has been running in Laos for 6 years (NAFRI – CIRAD) has already implemented the development of such Direct seeding Mulch-based Cropping systems (DMC).

Very interesting research and development work has been conducted by NTPC at the pilot village of Ban Nong Boua. This has made it possible to clearly identify the constraints for the farming of this land using conventional management sequences that are not suited to the zone. It has also shown the production constraints related to farm size (0.6 ha); **this is much too small to cover the staple food requirements of families (food crops-rice)**.

However, the programme on the introduction of varieties, compost production, vegetable and fruit production and training in these sectors has been very positive and should be applied to the 0.6 ha irrigable area using the same rational farming approach.

Through its contacts with PRONAE, NTPC has included DMC as a line for farming system development to be disseminated in its overall programme entitled 'Forest and Land Use Planning Allocation and Management' (FLUPAM).

The governing principles of DMC are **no tillage**, **permanent plant biomass soil cover** (dead or live mulch) **and direct sowing** or planting of perennial species in this mulch (fruit trees, cash crops and food crops).

The mechanisms induced by DMC give the following results:

• the soil is continuously replenished with organic matter and fertility generated;
• Water holding capacity is improved with the reduction of evapotranspiration;
• shade and allelopathy effects are created that control the entire weed complex;
• uptake of nutrients leached to a depth thanks to the powerful root systems of the cover crops;
• increase in macro-fauna and micro-fauna, improving biological porosity.

As a result, the main advantages of these systems are the maintaining and **improvement of fertility** (chemical, physical and biological), a **decrease in working time** (no tillage and above all less weeding), **increased production** and the stabilisation of cropping systems, that now become **sustainable**.

The cover plants with the best performance are **forage species—**legumes (*Stylosanthes guyanensis*) and Graminae (*Brachiaria*). NTPC introduced these on Nakai plateau and they grow under extreme conditions of acidity (pH 4.7).

They are very adaptable and are the best plants and sufficient to set up new sustainable DMC farming systems. They can be sown on degraded rangeland to create pasture and can be used combined with reforestation. Their protein value is excellent.

The different types of DMC systems that will be developed on Nakai plateau by FLUPAM are as follows:

- **imported biomass**: soil mulching for intensive vegetable crop systems (dead mulch) grown in irrigated perimeters;

- **biomass produced in crop rotations** and destroyed to provide mulch (dead mulch) for food cropping systems comprising cereals (rice and maize) or legumes (soybeans, beans);

- **permanent live plant cover** for agroforestry, fruits, perennial industrial crops, etc. The live plant cover can be used as animal feedingstuff after 2 or 3 years;

- **strips of live cover** providing mulch for cultivated strips **for all types of crop.**

When the crop fields are set out, as the **soil pH is very low**, resulting in acidity and aluminium toxicity, and there are serious phosphorus deficits, it will be necessary to plan thorough **corrective fertilisation** to optimise the establishment of the cover crops:

- **lime**: crushed limestone available in Laos Vang Vieng, (US$45 per tonne), 3-4 tonnes per ha;

- **thermophosphates**: slag available in the neighbouring provinces of Vietnam: 0.4 to 0.6 tonnes per ha (US$90 per tonne).

The cover crops planted must enhance these chemical soil correction functions, with references to comparable ecological situations in which they have been tested:

'T*he rate of sequestration of carbon in mulch-based cropping systems can be as rapid and as substantial as losses with inadequate management with or without tillage …. The trends in the evolution of exchange capacity in the soil strictly follow those of organic matter. Mulch influences the saturation level of the upper horizons of the cultural profile.*
Brachiaria type forage species grown for fairly long periods (3-4 years) play the role of 'cation pump' role and strongly increase the saturation level of the (useful) surface horizons as if strong doses of lime-magnesium amendments had been applied.' - L. Seguy *et al.*: *Système de culture et dynamique de la matière organique*, 2001).

The small land reserves available for farming throughout the resettlement zone mean that **cropping systems** must change. This means the **stopping of slash and burn systems** that are no longer sustainable because of the shortage of usable land area and in the light of the low productivity and the fragility of the soils.

Given initial rice productivity estimated at between 0.8 T/ha and 1.2 T/ha according to the zone, if DMC systems are developed with 3-year fallows, **it is necessary to plan a minimum of 3 ha of land per family with a 5-year rotation plan:**
- 2 years of rice/maize or rice/ cowpea or soybean;
- 3 years improved fallow (partly usable by cattle according to the restoration of fertility).

These essential areas for growing food crops must be prepared over and above the planned 0.6 ha of irrigated land destined mainly for vegetable and fruit crops (cash crops) with high value-added. These crops will also be grown using DMC (rational intensification).

The observations made during the mission show that it will be very difficult to provide usable agricultural areas for the food crops in two-thirds of the northern part of the resettlement area (because of the relief and the population density). It is possible in terms of area in the southern zone but it must be borne in mind that the soils there are the most degraded and the unit area per family could be from 4 to 5 hectares in order to cover requirements.

This analysis of the areas required for food crops—to ensure self-sufficiency in rice alone—is based on the need to **produce an average of 2 tonnes of paddy rice per family per year**, that is to say 1.5 T of rice to cover the requirements of 6 people each eating an average of 250 kg per year (national statistics).

The production of maize, cowpea and soybean in the rotations will complement food requirements and compensate for the loss of activity in other sectors currently exploited. Their sale or processing (feed for small-scale animal husbandry is an important sector) will earn complementary income for farmers.

IV. IMPLEMENTATION

The operational phase of the FLUPAM should start in June 2005. The 17 villages will be re-installed in 2006 and 2007 on the land visited during the mission.
The filling of the reservoir is planned for the end of 2009.

During the mission, the management of NTPC in Vientiane and the Nakai District Authorities made a strong request for us to present a **preliminary programme for the implementation of the actions to be conducted** for the resettlement of farmers. NTPC management has expressed the wish that we should attend the FLUPAM technical scheduling meetings for 2005-2006 within the limits of our possibilities.

1. Land

"Prime ministerial decree 193 of 29.5.2000 defines 20,000 ha resettlement area and specifies that the resettlement area and forest will be used by resettlers, allocated to families to establish houses and given to them for sustainable use".

The whole of the methodology concerning the land allocation component proposed by NTPC appears to us to be perfect but we consider that **priority should be awarded in 2005 to the continuous boundary marking of all the village land** so that, from the beginning, the newly settled farmers can:
- **see the land that they will have,**
- **devise their own strategies with regard to these new resources (forest, grazing land, cultivable land, fishing),**
- **identify their requirements.**

This spatial division of the land is essential even before the starting of the farming planned **if it is desired to have as much backing from the villagers as possible** for the programmes that will be proposed. It will make it possible according to the resources of each area of village land to orient programmes adapted to each condition and to optimise technical assistance (NTPC – DAFO).

These official boundaries of the new village land must serve as the legitimate framework for the subsequent awarding of title deeds **to each beneficiary family that will have access to all the ecosystems in the village land** : forest (wood and non-ligneous products), natural grazing land and lakes (fishing).

The second stage must be conducted following the marking of the boundaries of village land until 2009 when the families will settle definitively.

This phase require a prior rapid appraisal of the potential of each area of land. It will take into account the number of families to be resettled and the livestock to be shifted to these zones.

This must then be illustrated by comprehensible maps and discussed with the farmers using the same procedure as that used for the sites for houses and the 0.6-ha perimeters.

2. Farming

The actions to be performed for farming the village land areas must be ranked within the framework of an integrated development programme centred on 4 components:

• **rainfed food crops** that will be grown in the new cleared zones (**3,500 ha**);

• cash crops (fruit and vegetables) in the **irrigated perimeter**s (660 ha) in new cleared zones;

• improvement of **forage resources** in degraded rangeland for **rearing** large cattle (**6,000 ha**);

• exploitation and regeneration of **forests** for wood and non-ligneous products (**10,000 ha**).

When the families are resettled on this new land, priority will be given to ensuring self-sufficiency in rice, the obtaining of immediate income and ensuring the forage resources required for all the cattle.

2.1. Food crops

Developing DMC in this component requires addressing the clearing of 3 ha per family in 2005 in order to be able to sow the forage species *(Stylosanthes guyanensis* or *Brachiaria ruziziensis*) at the beginning of the rainy season in 2006.
The aim is to protect 3,500 ha with these forage species that are to restore degraded soils in these zones by restructuring them (chemically, physically and biologically) for 3 years. From 2009, when the reservoir is to be filled, use of these plots will start with food crops in the rotation plans described above. Some 20 kg per ha of forage seed will be required. Corrective fertiliser will be applied in split doses as follows:

- At the sowing of the forage plants – 2006:
    - 2 T/ha lime (calcium – magnesium)
    - 0.4 T/ha thermophosphate

- As a complement to maintenance dressing in subsequent years:

• 0.5 T/ha lime
• 0.2 T/ha thermophosphate

Maintenance dressing in the coming years will consist of an annual 0.4 t/ha 15 – 15 – 15 complete fertiliser split in two applications with the complementary fertilisation at the beginning and middle of the rainy season.

The forage species cultivated in this way will be protected from animals (fenced) and exploited for seed during the three years preceding cultivation.

A seed channel for the marketing of this seed could be envisaged. Regional demand for these species is strong.
The income generated for the farmers could be some $100 to $125 per ha.

Requirements for starting farming on the 3,500 ha would be approximately:
7000 T lime
1400 T thermophosphate
1400 T NPK 15–15–15
70 T seed

The estimated cost is approximately US$1,508M , that is to say $431 per ha.

Clearing the land will be performed **manually** with no machines (bulldozer, tractor with a blade, ploughs, etc.). **All the organic matter and the surface horizons must be conserved.**

All construction timber will be taken out and sold by the villagers (as a group). The remaining wood will be recovered for building fences and firewood.

All the shoots and leaves will be left on the land and **not burned** to optimise organic matter resources.

Grazing land will be sown in the residual mulch at the first rains in 2006.

The best land at the edge of the village land and that will be flooded in 2009 should be identified for covering family rice requirements during the transition phase. The land will be farmed in the traditional way (slash and burn) and sown with upland rice. Machines (chainsaws, direct seeding apparatus, threshers, power-driven cultivators) and inputs will be provided for the farmers to optimise their labour and increase production.

It would be a good thing to grow a surplus and establish safe common village grain stores to help families that have problems.

Activities during the 2005 – 2009 transitory phase have a twin objective:

- **regenerating soils** that will finally be used in the farmers' DMC systems;

- **cleaning the reservoir**.

2.2. Irrigated perimeters

Development of the 660 ha will be identical to that described for food crops. The costs will be the same at $431 per ha, i.e. a total of $218,460 for all the land.

These crop fields will be reserved exclusively for intensive market garden crops and fruit arboriculture. Hedges of forage shrubs could be planted and the prunings used as complementary feed for ruminants.

The DMC soil management system in alternate strips should be used. These strips follow the contours. This mean a 3 m strip of *Brachiaria ruziziensis* alternated with a 3 m crop strip. The part where the forage species is grown will be mown periodically to provide mulch for the cultivated strip.

With this DMC soil management system, it can be planned to grow crops on the forage strip every three years. The forage course enters the rotation systems after supplying the systems with biomass and regenerating the soil its grows on (chemical, physical and biological restructuring) thanks to the powerful root system that can attain a depth of 2 m.

The crop perimeter is covered at all times, making it possible to prevent erosion and weed regrowth. The permanent mulching system for crops also saves 50% of water resources. Water labour time is decreased in the same proportion and weeding time is reduced by about 90%. Mowing the cover crop strips can be mechanised.

Mulching systems for vegetable crops greatly reduce attacks by fungal and bacterial complexes (by about 70% in Gabon).

All terrace development and contouring with erosion control cordons is forbidden. The fragility of the soils cannot stand this and the labour costs and time are prohibitive.

The investment originally planned for terrace development will be used to install sprinkler irrigation systems for the perimeters.

Village water management committees must be formed from the beginning so that the management of the network is finally handled by the farmers.

Vegetable and fruit growing plans must be drawn up according to demand. Considerable initial support should be planned for supplies and marketing and training provided for growing these new crops.

The compost preparation units planned in each village will mainly be used for these crops.

Only 3,000 m2 will be devoted to market garden crops each year with this alternate strip DMC system. However, depending on the evolution of fertility, part of the mown material from the forage species can be used to complete the feed of large ruminants; this will be combined with the pruning of bush legumes planted as field hedges. The forage strips can also be exploited for seed production during certain periods.

Finally, varietal trials must be conducted on vegetable varieties to enable the production of lettuces and tomatoes (very high value-added) during the rainy season. This is performed in Gabon in DMC systems using tested tropical varieties that should be introduced.

For fruit production, the two existing DAFO – NTPC nurseries must be strengthened to cover requirements. The species introduced for dissemination must be strictly controlled. Sources of supply must be reliable, especially for citrus fruits (with regard to fungal and bacterial complexes).

The species extended must meet production and quality criteria and produce fruits that are easy to sell. Prospective studies must be carried out for this for supplies of seedlings and rootstocks and for packing and marketing.

2.3. Livestock – Grazing land

Studies show that the buffaloes and bovines currently total about 4300 to 4700 head. More than 85% of the total consists of buffaloes. Some herds are large, with several tens of head. In most cases, rearing large ruminants forms the savings of farms and is also used for transfer of fertility.

The censuses show that 52% of families own at least one head of cattle. It is planned in the resettlement programme to allocate every non-owner family with two head of cattle (for manure production and as initial capital).

This arrangement would increase the total to between 5400 and 5800 head, that is to say an increase of nearly 20%.

The studies performed also show that the present livestock grazing on the 57,000 ha of Nakai plateau would seem to have forage resources problems for 3 months during the dry season.

Examination of the land resources that could be used for livestock after the filling of the reservoir shows a total of about 6000 ha of sparse forest and 2000 ha of flood recession land in the reservoir. It will only be possible to use the latter land for 5 months a year.

In the 6000 ha of sparse forest on very acid, degraded soils, it is possible to develop *Brachiaria brizantha* grazing land in combination with forest regrowth. *B. brizantha* is well suited to acid soils and has a high forage value. The best part of the forest regrowth could be conserved and 70% of the land devoted to grazing.

The exploitable species in Laos for the recession zones of the reservoir is *Brachiaria mutica*. It is very difficult at the present stage to be certain that this land can be used to a significant extent.

Before the filling of the reservoir, priority would be awarded to set up the 6,000 ha of sparse forest as grazing land in 2006 to meet requirements when the farmers become installed definitively.

Document obtenu sur le site Cirad du réseau http://agroecologie.cirad.fr

As for the food crop component, bottom and maintenance dressing must be applied on the basis of US$ 431 per ha, that is to say a cost of some US$ 2,586,000, not counting labour and fencing.

The allocation of these plots must be performed fairly and each family must have sole control of at least 5 ha of this land; it will be fenced and hedged with fast-growing forage species (*Acacia mangium, Acacia auriculiformis,* etc.).

The improved fallows in the food crop systems can in time be partially exploited (*Stylosanthes guyanensis, Brachiaria ruziziensis*) by mowing and drying to cover dry season forage requirements. The production area would total some 1,000 to 1,200 ha. In certain villages, depending on the size of herds and the areas available, it will certainly be necessary to reduce the number livestock reared by certain families if fair access to these resources is desired.

The potential for use as natural grazing land must be appraised rapidly in the remaining 10,000 ha of forest.

We consider that a reduction in the total head of livestock should be envisaged in relation to the resources and the difficulties that the farmers will come up against in a rapid change to intensive forage management systems.

Allowing for the areas that can be developed as improved grazing land, the partial use of the forage produced in the DMC food crop systems and the use of crop residues, we consider that an average of 3 large ruminants per family would be acceptable. This gives a stocking level of 1 head on about 2 ha considering the low productivity of the grazing land during the dry season.

This would give a total of about 3,500 head for the entire resettlement zone.

Considerable scheduling work must be undertaken with the farmers and each area of land addressed separately according to the resources available. It must clearly be taken into account that 48% of the families do not possess large ruminants today and that the allocation (2 head per family) must be addressed before the development of the land.

The livestock allocated to them will be purchased from the farmers who must reduce their herds.

The programme must fund a manure stable with a hay barn for each family. In semi-stalling with good straw management, manure production is some 5 to 6 tonnes per head of cattle. Three head per family would give 15 to 18 T of manure that would be used entirely for the 0.6 ha of intensive market garden crops.

2.4. Forests.

There probably remains some 10,000 ha of secondary forest that is degraded to varying degrees. Appraisal of the resources in each village area must be carried out in 2005 to evaluate the exploitable ligneous and non-ligneous species. A programme for the sustainable use of these resources must be discussed with each village. Multi-species reforestation plans with fast and slow-growing species and exploitation plans must be envisaged.

Each family should have an equal share in the sector that will be managed by village groups.

Exploitation of the forest will be combined with the hedging of crop fields and grazing land and the partial regeneration of forest regrowth in the grazing land.

3. Technical assistance – Human resources

Present human resources are markedly insufficient for implementing such a programme. A recruitment plan with DAFO is to be started in June 2005 for Laotian technical assistance.

A minimum of one engineer per village should be planned. His practical training under immersion conditions in the environment will be completed to generate general skills that can be used in all the components of the farming systems (agriculture, livestock, forestry and fishing).

The setting up of the following units should be planned at Operations Management and DAFO:

- a training-management unit of 5 or 6 persons to complete the training of the field extension officers, to produce the necessary training material and to participate in the management and training of groups of farmers;

- a marketing support, credit and supply unit made up of 3 or 4 persons who will first of all concentrate on the entire logistics of supplying the villages with inputs, equipment and seed. Distribution stores should be planned in each village. Their management will in time be transferred to the farmers or to the private sector;

- a planning and logistics unit with 2 persons to identify possible sources for the introduction of plant material and animals, sources of agricultural equipment and inputs and to draw up orders according to the requirements of the programmes;

- a research & development unit with 2 extension agents to test and validate all the innovations that could be made and extended. They will also be in charge of seed and plant multiplication.
This unit will be based on existing DAFO and NTPC structures (nurseries to be optimised) and use village fields negotiated for demonstration purposes (1 to 2 ha per village).

All the components—agriculture, forestry, livestock farming and fishing—must be strongly integrated and operate as a network using joint programmes. The village area approach will be favoured in a participative framework. All the programmes will be discussed with the villages beforehand.

With regard to the DMC approach, FLUPAM can call on foreign consultants living in Laos who participated in the implementation of the National Agroecology Programme (PRONAE) and also develop a strong partnership with PRONAE (NAFRI/CIRAD) for training and all research and adaptive trial aspects. We consider that the mobilisation of these two resource networks is necessary in order to optimise NTPC technical assistance capacities. A partnership framework can be defined and set up during the second half of 2005.

Finally, substantial complementary human and material resources should be planned to strengthen farmers' capacity to perform this development operation.

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ANNEXES

Mission calendar

Monday 9 May:
- Working meeting to prepare the mission with NTPC (Chris FLINT, Mr HOY PHOMVISOUK and Jean FOERSTER) and Florent TIVET.
- AFD meeting with Mr Etienne WOITELLIER, Agency Director

Tuesday 10 May:
- Trip from VIENTIANE to OUDOMSOUK
- Working meeting to prepare the field visits with Messrs IMPASITH THATHONGSAKD (SRO), KHAMHAUNG, KHAM HUNG SOUKHAVADY of NTPC and Mrs NALY LOUANG CHANTHALATHA and Mr WATTHANAKONE SOULINYA of DAFO

Wednesday 11 May:
- Field visits to the future resettlement sites planned and the old villages of Khone Kaen, Ban Done, Sop On, Boua Ma and Phonesavang (NTPC experimental site)

Thursday 12 May:
- Field visits to the resettlement sites planned: Nong Boua (pilot village), Phon Phan Pek, Sopma, Oudomosouk, Nakai Neua and Nakai Taï.
- Visits to the NTPC – DAFO fruit nurseries at Nakai Neua

Friday 13 May:
Field visits to the new resettlement sites of Nongbouakhan, Sophene and Thalang
Meeting with Mr KEYOUDON SILAVONG, head of the NTPC Forestry Department
Visit to pilot reforestation plots at Ban Nong Boua pilot village

Saturday 14 May:
- Report meeting with Mr IMPASITH THATHONGSAKD and the NTPC – DAFO technical teams.
- Visit to the NTPC experimental site at Ban Phonsavang.

Sunday 15 May:
- Field visits in the southern zone (Khone Kaen, Ban Done)
- Visit to Ban Nong Boua pilot village
- Discussion with the NTPC agricultural technical teams.

Monday16 May:
- Report meeting with Mr HOY PHAMVISOUK and the Head of the Agricultural and Forestry Services of Oudomsouk District (DAFO)

- Return toVIENTIANE

Tuesday 17 May:
- Report meeting with AFD and Florent TIVET (CIRAD)
- Bibliography

Wednesday 18 May:
- Report meeting at NTPC with Messrs Jean FOERSTER, HOY THATHONGSAKD and Florent TIVET (CIRAD).
- Report writing.

Soil analysis sheet

	Lab. No.	1	2	3	4	5	6	7	8	9
	Identification	NK.11	NK.12	NK.13	NK.21	NK.22	NK.23	NK.31	NK.32	NK.33
	Depth (cm)	0-8	0-35	35-60	0-8	8-30	30-50	0-20	20-45	45-60
Morphopedological unit		Plateau / sandstone			Plateau / sandstone			Non-floodable Present alluvium		
Grain-size distribution (%)	Clay (0-2µ)	12,70	18,20	22,60	7,70	22,20	30,50	27,40	41,30	40,70
	Fine silt (0-20µ)	8,90	10,00	9,80	10,00	10,80	14,50	37,40	3250	29,10
	Coarse silt (20-50µ)	16,90	17,30	17,40	17,60	14,80	9,80	17,90	13,20	14,90
	Fine sand (50-200µ)	57,20	51,50	47,50	57,30	43,80	28,20	6,20	12,80	15,00
	Coarse sand (200-2000µ)	4,30	3,00	2,80	7,40	8,30	17,00	1,20	0,30	0,30
Organic matter	%	4,09	1,16	0,44	2,52	0,61	0,67	4,33	0,54	0,57
	C/N	21,96	17,13	11,88	22,99	12,42	8,94	15,40	8,93	9,12
pH– water		4,46	4,39	4,70	5,14	4,78	4,90	5,01	4,78	4,85
Phosphorus (mg/kg)	Total	102,50	79,25	79,25	104,75	98,25	259,75	455,25	215,50	318,25
	Assimilable (Olsen)	2,55	1,29	1,29	2,65	1,47	1,48	5,92	5,34	4,51
Exchange complex me100g	Ca^{+++}	0,08	0,05	0,04	0,235	0,04	0,13	0,91	0,12	0,13
	Mg^{+++}	0,10	0,07	0,06	0,24	0,11	0,12	0,41	0,09	0,14
	K^{+}	0,09	0,06	0,06	0,17	0,08	0,16	0,10	0,05	0,05
	Na^{+}	0,02	0,02	0,02	0,03	0,02	0,03	0,03	0,02	0,02
	S	0,30	0,20	0,17	0,67	0,25	0,44	1,45	0,27	0,34
	CEC	3,23	3,09	3,91	1,81	3,32	5,98	4,04	4,56	4,39
	Saturation level (%)	9,25	6,48	4,40	36,72	7,48	7,29	35,89	5,92	7,63
	Al^{+++}	2,10	2,17	2,91	0,64	2,31	4,49	1,70	3,13	2,75
	Al/CEC	65,0	70,2	74,7	35,4	69,6	75,1	42,1	68,6	62,6

CIRAD Laboratory - Montpellier

Soil analysis sheet

Lab. No.		10	11	12	13	14	15	16		
Identification		NK.41	NK.42	NK.43	NK.44	NK.51	NK.52	NK.53		
Depth (cm)		0-8	8-20	20-40	40-60	0-10	10-35	35-65		
Morphopedological unit		Plateau / sandstone				Mid-terrace Recent alluvium				
Grain-size distribution (%)	Clay (0-2µ)	4,2	5,30	15,00	8,30	21,90	21,70	29,10		
	Fine silt (0-20µ)	3,70	4,40	8,80	10,90	11,10	12,00	8,50		
	Coarse silt (20-50µ)	9,90	9,70	9,50	8,30	12,50	14,10	11,70		
	Fine sand (50-200µ)	79,90	78,20	60,30	47,80	46,20	45,90	45,00		
	Coarse sand (200-2000µ)	2,20	2,40	6,40	24,80	8,40	6,40	5,70		
Organic matter	%	1,65	0,52	0,49	0,17	4,92	2,71	1,50		
	C/N	19,25	12,98	11,95	10,57	12,97	14,55	14,86		
pH– water		4,89	4,81	4,84	5,03	4,44	4,77	4,69		
Phosphorus (mg/kg)	Total	60,50	65,50	57,75	49,25	220,75	173,25	164,5		
	Assimilable (Olsen)	2,06	1,88	1,02	1,02	2,60	1,93	1,27		
Exchange complex me100g	Ca^{+++}	0,13	0,04	0,04	0,05	0,11	0,03	0,03		
	Mg^{+++}	0,07	0,04	0,04	0,08	0,12	0,04	0,02		
	K^{+}	0,06	0,03	0,03	0,06	0,13	0,05	0,13		
	Na^{+}	0,02	0,02	0,02	0,02	0,02	0,01	0,03		
	S	0,27	0,11	0,13	0,21	0,38	0,13	0,21		
	CEC	0,96	0,68	2,49	5,15	2,32	1,68	1,53		
	Saturation level (%)	27,80	16,52	5,38	4,10	16,46	7,70	13,54		
	Al^{+++}	0,43	0,35	1,83	3,76	1,64	1,22	1,08		
	Al/CEC (%)	44,8	51,5	73,5	73,0	70,7	72,6	70,60		

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Soil analysis sheet

	Lab. No.	17	18	19	20	21	22	23	24
	Identification	NK.61	NK.62	NK.63	NK.71	NK.72	NK.81	NK.82	NK.83
	Depth (cm)	0-10	10-45	45-60	0-5	5-18	0-10	10-35	35-60
Morphopedological unit		Plateau / sandstone			Plateau / sandstone		Mid-terrace recent alluvium		
Grain-size distribution (%)	Clay (0-2µ)	5,90	11,90	20,90	15,80	17,30	37,20	32,60	35,60
	Fine silt (0-20µ)	7,20	8,40	9,20	8,30	9,30	16,00	9,20	5,90
	Coarse silt (20-50µ)	21,20	21,30	25,90	17,40	17,00	2,90	6,00	6,70
	Fine sand (50-200µ)	60,80	55,80	41,50	56,70	54,40	27,90	28,70	28,70
	Coarse sand (200-2000µ)	4,90	2,60	2,50	1,70	2,10	16,00	23,50	23,00
Organic matter	%	2,40	0,50	0,39	3,86	2,23	4,85	2,15	1,28
	C/N	19,90	13,20	10,54	14,28	13,50	14,21	14,81	14,79
pH – water		4,75	4,89	4,97	6,10	5,49	4,31	4,59	4,62
Phosphorus (mg/kg)	Total	77,00	53,75	70,25	169,50	112,75	247,00	194,25	195,00
	Assimilable (Olsen)	2,20	0,65	1,20	4,84	3,40	6,25	3,33	3,20
Exchange complex me100g	Ca^{++}	0,20	0,06	0,05	3,44	2,20	0,31	0,07	0,04
	Mg^{++}	0,11	0,11	0,10	1,08	0,41	0,14	0,05	0,02
	K^{+}	0,08	0,05	0,12	0,56	0,15	0,14	0,08	0,07
	Na^{+}	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,02
	S	0,40	0,24	0,28	5,09	2,78	0,61	0,22	0,14
	CEC	1,60	2,18	3,71	5,79	3,64	2,19	2,20	1,98
	Saturation level (%)	25,13	10,85	7,54	87,99	76,32	27,61	10,14	7,03
	Al^{+++}	0,73	1,48	2,50	0,02	0,26	1,49	1,46	1,49
	Al/CEC (%)	45,6	67,9	67,4	0,3	7,1	68,0	66,4	75,3

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Soil analysis sheet

Lab. No.		25	26	27	28	29	30	31	32	
Identification		NK.91	NK.92	NK.101	NK.102	NK.103	NK.111	NK.112	NK.113	
Depth (cm)		0-8	8-25	0-8	8-46	46-60	0-8	8-15	15-45	
Morphopedological unit		Plateau / sandstone		Plateau / sandstone			Plateau / sandstone			
Grain-size distribution (%)	Clay (0-2µ)	10,50	18,90	14,30	23,30	30,10	7,80	11,40	20,40	
	Fine silt (0-20µ)	15,90	15,70	10,10	9,60	10,40	9,20	9,80	12,90	
	Coarse silt (20-50µ)	41,30	36,60	21,20	20,10	20,20	32,60	33,40	29,80	
	Fine sand (50-200µ)	30,40	24,70	49,80	43,50	36,40	45,40	41,10	33,40	
	Coarse sand (200-2000µ)	1,90	2,20	4,60	3,50	2,90	4,90	4,30	3,40	
Organic matter	%	3,18	1,01	2,08	0,87	0,83	1,89	0,72	0,65	
	C/N	21,98	16,51	15,65	15,18	14,89	18,92	13,67	10,99	
pH – water		5,32	5,03	4,98	4,82	4,89	5,18	4,74	4,65	
Phosphorus (mg/kg)	Total	136,00	130,00	142,25	108,50	110,25	102,50	109,25	124,25	
	Assimilable (Olsen)	3,63	2,58	4,12	2,28	2,15	3,55	2,82	2,20	
Exchange complex me100g	Ca^{++}	0,90	0,44	0,33	0,04	0,07	0,62	0,12	0,05	
	Mg^{++}	0,33	0,27	0,37	0,15	0,18	0,28	0,12	0,10	
	K^{+}	0,10	0,06	0,14	0,21	0,17	0,11	0,05	0,08	
	Na^{+}	0,02	0,02	0,04	0,02	0,02	0,02	0,02	0,03	
	S	1,35	0,80	0,88	0,42	0,43	1,03	0,32	0,25	
	CEC	2,21	2,68	2,40	3,80	4,74	1,86	1,94	3,74	
	Saturation level (%)	60,90	29,77	36,83	10,95	9,12	55,58	16,35	6,75	
	Al^{+++}	0,54	1,42	1,02	2,55	3,38	0,54	1,36	2,78	
	Al/CEC (%)	24,4	53,0	45,5	67,1	71,3	29,0	70,1	74,3	

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Soil analysis sheet

		33	34	35	36	37	38	39	40	41
Lab. No.		33	34	35	36	37	38	39	40	41
Identification		NK.121	NK.122	NK.123	NK.131	NK.132	NK.133	NK.141	NK.142	NK.143
Depth (cm)		0-13	13-30	30-70	0-15	15-35	35-70	0-20	20-60	60-140
Morphopedological unit		Valley-side			Valley-bottom			Non-floodable present alluvium		
Grain-size distribution (%)	Clay (0-2µ)	7,40	9,90	9,80	12,00	16,60	17,50	32,10	33,50	26,00
	Fine silt (0-20µ)	4,60	4,50	4,40	8,10	6,80	6,60	30,90	34,20	23,00
	Coarse silt (20-50µ)	7,90	7,40	9,00	10,60	10,00	10,00	15,70	19,00	2250
	Fine sand (50-200µ)	68,30	65,60	63,50	56,60	56,80	56,90	20,20	13,00	27,90
	Coarse sand (200-2000µ)	11,70	12,60	13,30	11,60	9,70	11,10	1,00	0,40	0,60
Organic matter	%	2,11	0,94	0,50	1,26	1,02	0,59	4,16	5,20	2,08
	C/N	16,68	15,37	14,79	13,29	13,36	10,80	12,39	12,94	13,24
pH – water		4,89	4,91	4,71	4,67	4,37	4,72	5,35	5,03	4,93
Phosphorus (mg/kg)	Total	147,25	88,25	58,50	129,00	111,25	114,00	465,05	423,75	298,00
	Assimilable (Olsen)	3,30	2,40	2,45	3,80	2,80	2,60	2,60	2,50	2,35
Exchange complex me100g	Ca^{++}	0,05	0,03	0,04	0,15	0,08	0,12	0,09	0,08	0,04
	Mg^{++}	0,09	0,04	0,03	0,04	0,03	0,03	0,06	0,05	0,03
	K^{+}	0,08	0,05	0,05	0,06	0,03	0,03	0,07	0,05	0,07
	Na^{+}	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03
	S	0,24	0,13	0,14	0,27	0,16	0,20	0,24	0,20	0,17
	CEC	1,43	1,28	1,48	1,84	2,55	2,29	2,67	2,49	2,15
	Saturation level (%)	16,40	10,27	9,56	14,86	6,12	8,77	8,84	7,97	8,03
	Al^{+++}	0,91	0,85	0,91	1,25	2,04	1,77	1,56	1,59	1,38
	Al/CEC (%)	63,6	66,9	63,6	67,9	80,0	77,3	58,4	63,9	64,2

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Soil analysis sheet

Lab. No.		42	43	44						
Identification		NK.151	NK.152	NK.153						
Depth (cm)		0-10	10-30	30-75						
Morphopedological unit		High terrace								
Grain-size distribution (%)	Clay (0-2µ)	15,10	16,15	21,29						
	Fine silt (0-20µ)	10,20	8,45	6,82						
	Coarse silt (20-50µ)	9,20	8,92	10,08						
	Fine sand (50-200µ)	58,40	60,34	54,63						
	Coarse sand (200-2000µ)	7,20	6,15	7,18						
Organic matter	%	3,06	0,67	1,47						
	C/N	13,55	12,65	14,40						
pH – water		4,70	4,73	4,69						
Phosphorus (mg/kg)	Total	106,50	65,25	74,50						
	Assimilable (Olsen)	2,65	2,01	1,85						
Exchange complex me100g	Ca^{++}	0,05	0,04	0,05						
	Mg^{++}	0,09	0,05	0,04						
	K^{+}	0,10	0,05	0,04						
	Na^{+}	0,15	0,02	0,02						
	S	0,39	0,15	0,14						
	CEC	2,75	2,34	3,30						
	Saturation level (%)	14,02	6,54	4,24						
	Al^{+++}	2,09	2,00	2,45						
	Al/CEC (%)	76,0	85,5	74,2						

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